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Nationwide Urban Runoff Program
Tampa, Florida: Water Quality Assessment of the Lower Hillsborough River - Final Report

Tampa Dept. of Public Works, FL

Prepared for

Environmental Protection Agency, Washington, DC

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CITY OF TAMPA

TAMPA, FLORIDA 33602

WATER QUALITY ASSESSMENT
OF THE
LOWER HILLSBOROUGH RIVER
FINAL REPORT

October, 1983

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This report provides the results of the sampling, monitoring, evaluation and analysis of data to better characterize the water quality in the estuary of the Hillsborough River, and determination of the impact of stormwater runoff on this water body.

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November 3, 1983

J-7739

Mr. Ron Giovanelli
City of Tampa
Department of Public Works
City Hall Plaza-5th Floor
Tampa, FL 33602

Dear Mr. Giovanelli:

In accordance with our Agreement dated July 6, 1981 and subsequent amendments, we are pleased to submit the Final Receiving Water Report for the Tampa Nationwide Urban Runoff Program Study.

Results and findings of the Tampa Nationwide Urban Runoff Program and Receiving Water Study are presented in five (5) final reports including Appendices and fourteen (14) individual task outputs. Included among the final reports are:

1. Phase I Receiving Water Study,
2. Phase II Final Report,
3. Phase III Stormwater Management Plan,
4. Lower Hillsborough River Report, and
5. Final Summary Report.

This study was conducted by Messers. David R. Bingham and Paul N. Singarella, Ms. Katherine O. Thompson and Ms. Meredith G. Durant of Metcalf & Eddy, under the direction of Dr. Abu M.Z. Alam.

We thank you for the cooperation and assistance which you have provided to us during the conduct of the work. It has been a pleasure to work for the City on this important project. We look forward to our continued association with the City of Tampa on future assignments.

Very truly yours,

Abu M.Z. Alam

Abu M.Z. Alam
Associate

AMZA/jln

RECEIVING WATER STUDY

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CHAPTER 1

INTRODUCTION

In conjunction with its participation in the Nationwide Urban Runoff Program (NURP), the City of Tampa has sponsored a study of the lower Hillsborough River estuary. The intent of the study is to better characterize water quality in the estuary through the collection and analysis of new data and to determine the impact of stormwater runoff on this water body.

Tampa NURP Study

The NURP study addressed the issues of stormwater runoff quantity and quality in terms of flooding problems and pollution loads to the lower Hillsborough River estuary. This study consisted of three phases.

Phase I. In Phase I of the Tampa NURP study an assessment was made of the most recent water quality data to identify possible problems and to investigate a cause and effect relationship between urban stormwater runoff and changes in water quality in the receiving waters near Tampa (1). Phase I of the NURP Study focused on analysis of data collected in Hillsborough Bay, the lower Hillsborough River, and Hillsborough Reservoir. Since it is most desirable to study the impact of urban stormwater runoff where it can be most readily isolated, the three receiving water bodies were analyzed to determine which was best suited for the study of urban stormwater runoff. To do this, each water body was tested against several criteria. The results indicated that the effects of stormwater runoff would be best studied in the lower Hillsborough River, followed by the Reservoir, and the Bay.

Phase I results indicated that violations of State standards for dissolved oxygen and coliform concentrations occur in the lower River. The dissolved oxygen concentrations are affected by the freshwater flow in the River. At lower flows, salt water penetrates into the lower River and bottom sediments exert a large oxygen demand. Under these conditions, dissolved oxygen concentrations are consistently below 4.0 mg/l and at times equal to zero in the bottom waters. Generally the lowest DO concentrations occur in the middle reaches of the River 2 to 6 miles below the Tampa Dam. Fecal coliform concentrations in the lower River periodically violate State standards with concentrations measured above 100,000 MPN/100 ml. The higher coliform concentrations occur after wet periods. High coliform counts occur throughout most of the River. In addition, suspended solids concentrations appear to increase after wet weather.

The receiving water data available for the Phase I study consisted primarily of single monthly samples. These data were not adequate to establish a cause and effect relationship between urban runoff and receiving water problems. A more detailed data collection and analysis program was therefore developed for the lower Hillsborough River to be conducted simultaneously with the NURP Project. In this way the characterization of stormwater flows and loads from urban drainage basins performed during the

NURP study would be coordinated with measurements and analysis of the receiving waters.

Phases II and III. Phase II of the study included data collection and analysis of rainfall, stormwater runoff and stormwater controls (2). Phase III involved the development of a Stormwater Management Plan which supports the City's efforts to deal with flooding problems, takes into account the impact of stormwater runoff on the lower Hillsborough River and incorporates the State requirements for stormwater permits (3).

Report Organization

The lower Hillsborough River study involves data collection and analysis, mathematical modeling, and alternatives assessment. Chapter 2 presents measurements and analysis of continuous time series flow, salinity, dissolved oxygen and temperature data. Synoptic surveys used to gather extensive water quality data along the River under a variety of conditions are presented in Chapter 3.

The calibration and verification procedures for the selected river model used to simulate both existing and future water quality conditions are described in Chapter 4. Chapter 5 discusses the vertical variation of water quality and presents methods for estimating the vertical variation of salinity and dissolved oxygen in the River water column. Finally, Chapter 6 identifies the major water quality problems in the lower Hillsborough River and presents a series of alternatives and the subsequent improvements to the water quality conditions in the River.

REFERENCES

1. Metcalf & Eddy, Inc., Phase I - Receiving Water Study, City of Tampa, Tampa Nationwide Urban Runoff Program Study, December, 1981.

2. Metcalf & Eddy, Inc., Phase II Report. Task II.6 Runoff Characterization Data Analysis, Task II.9 Control Testing - Data Analysis, Task II.10 Projection of Study Area-Wide Loadings, Task II.11 Monitor other NURP Projects, City of Tampa, Tampa Nationwide Urban Runoff Program Study, October, 1983

3. Metcalf & Eddy, Inc., Phase III Stormwater Management Plan, City of Tampa, Tampa Nationwide Urban Runoff Program Study, October, 1983.

CHAPTER 2

CONTINUOUS DATA

General

The lower Hillsborough River in Tampa is an estuary and its water quality is dependent on many interactive phenomena. These include the following:

1. Freshwater discharge (and its quality) from the Hillsborough Reservoir.
2. Tidal variation and water quality in Hillsborough Bay.
3. Stormwater runoff from the City of Tampa.

The freshwater discharge from the Hillsborough Reservoir varies seasonally and is highest in August and September during the wet season. During this period estuarine characteristics disappear almost entirely from the upper segments of the River. During times of very low discharge from the Reservoir, saline intrusion occurs and the water quality of Hillsborough Bay affects River water quality.

In order to evaluate the effects of various hydrologic and climatological conditions on the lower Hillsborough River, a continuous data collection program was conducted. The measurements were carried out by the U.S. Geological Survey. The purpose of this Chapter is to present and analyze the data from the continuous measurement program, thus characterizing the influence of various parameters and their interaction on the lower Hillsborough River hydrodynamics and water quality.

Continuous time-series data were collected during a 15-month period (July, 1981 through September, 1982) at Platt Street, Columbus Drive, Sligh Avenue and 22nd Street. These four stations are shown in Figure 2-1. The tidal stage was measured using continuous recording meters and digitized at fifteen minute intervals. In the same manner temperature, dissolved oxygen and conductivity were continuously measured and digitized at hourly intervals. At each station, meters were located at approximately mid-depth in the center of the stream.

The time series data were digitized and stored on computer tape by the USGS. The data were analyzed using Metcalf & Eddy's ODAP (Oceanographic Data Analysis Package) program. Time series computer plots were generated and statistical analyses were performed on the data. A discussion of the results of the analysis follows.

Tides

Figure 2-2 presents a computer plot of the tidal height at Platt Street from mid-April to the end of May, 1982. The tides in this area exhibit both diurnal (recorded on April 30) and semi-diurnal (recorded on May 5) characteristics, and generally have an amplitude of 2 to 4 feet.

The tidal wave progresses up the River without interference until upstream of Sligh Avenue. A discrepancy was noted at times between gage heights at 22nd Street and at the other stations. As seen in Figure 2-3, from October 1 through

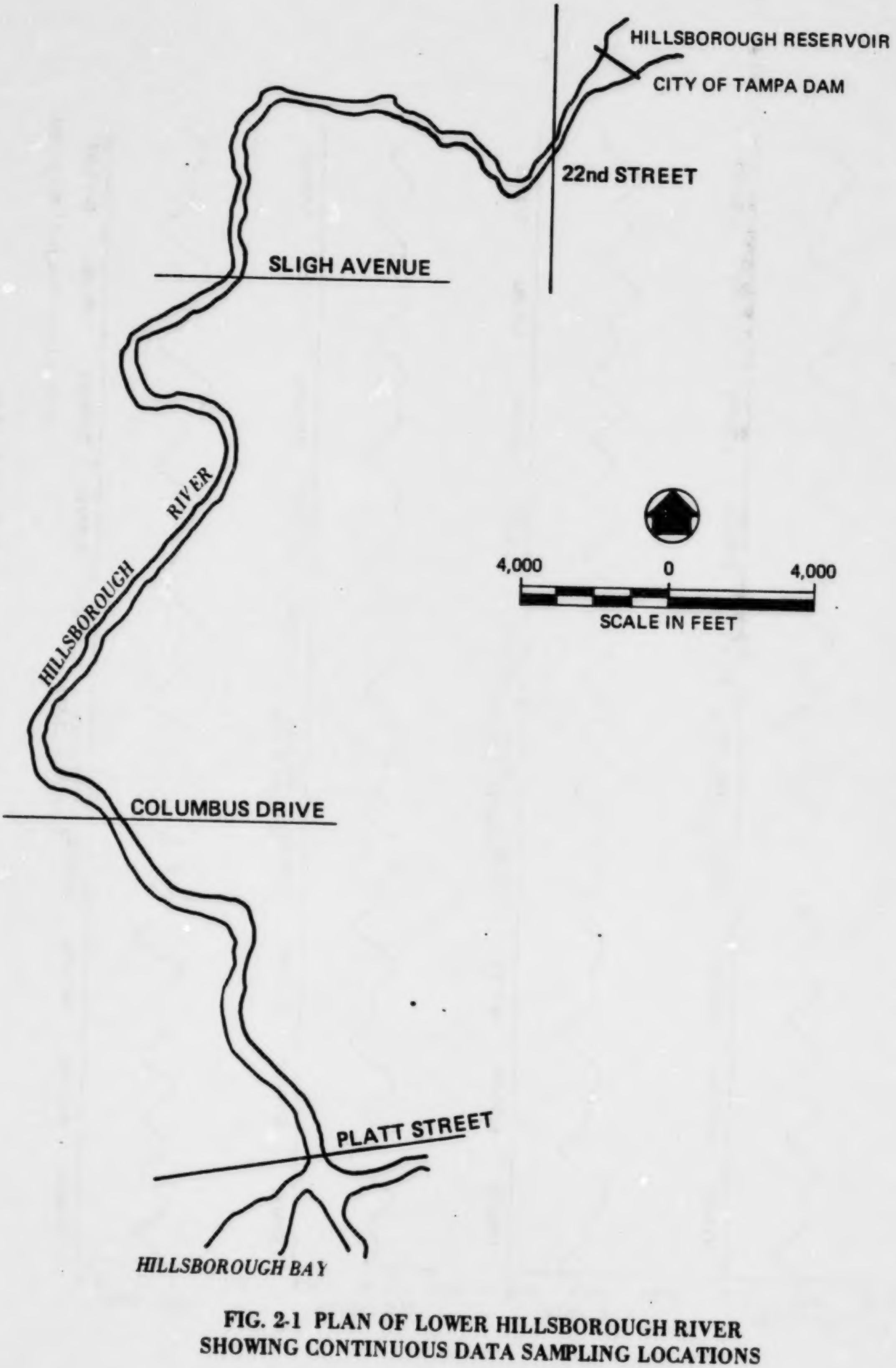
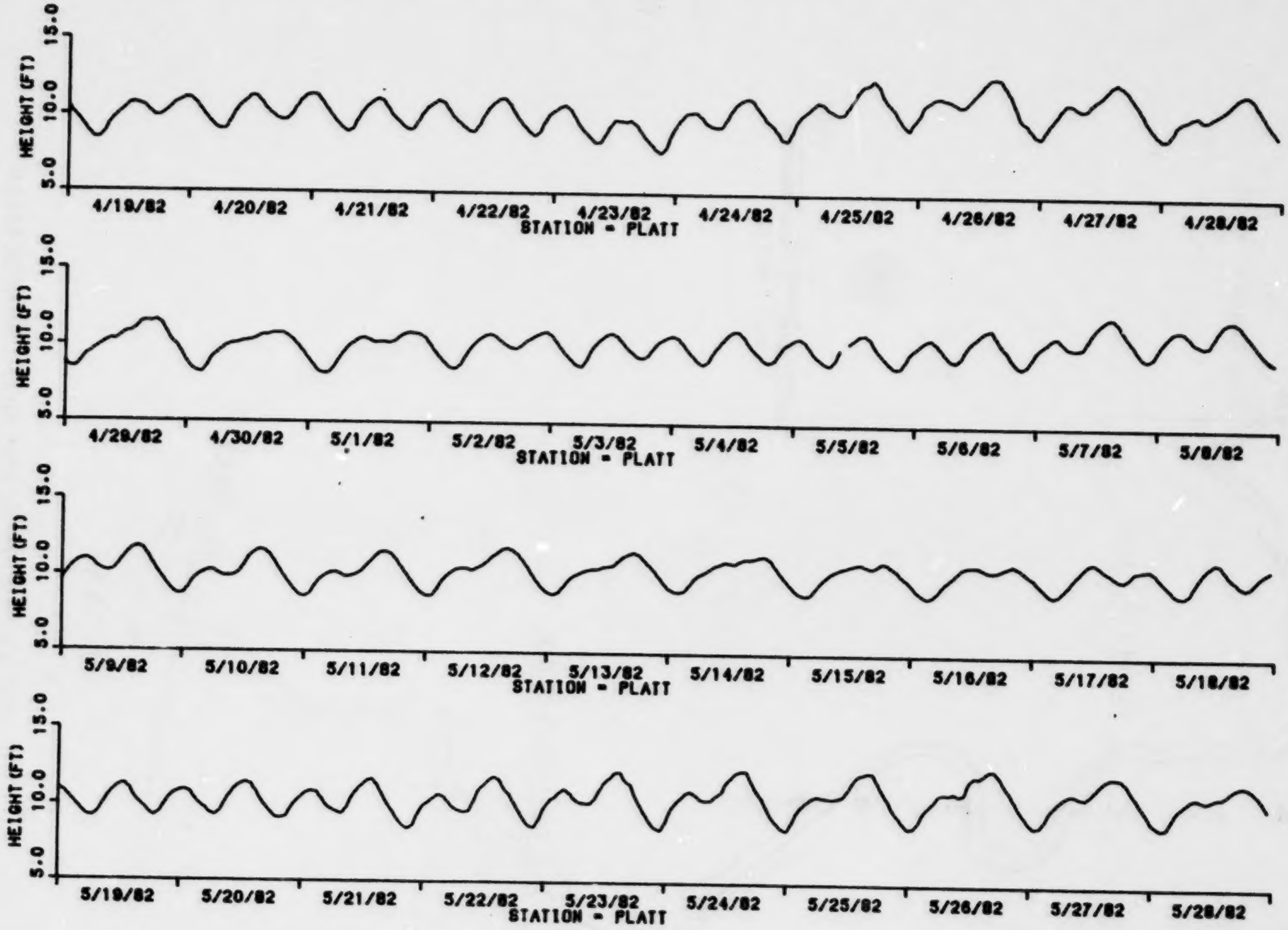

HILLSBOROUGH RESERVOIR
CITY OF TAMPA DAM
22nd STREET
SLIGH AVENUE
HILLSBOROUGH RIVER
4,000
0
4,000
SCALE IN FEET
COLUMBUS DRIVE
PLATT STREET
HILLSBOROUGH BAY

FIG. 2-1 PLAN OF LOWER HILLSBOROUGH RIVER SHOWING CONTINUOUS DATA SAMPLING LOCATIONS



NOTE: GAGE DATUM 10 FT. BELOW MSL

FIG. 2-2 GAGE HEIGHT AT PLATT STREET, APRIL-MAY, 1982

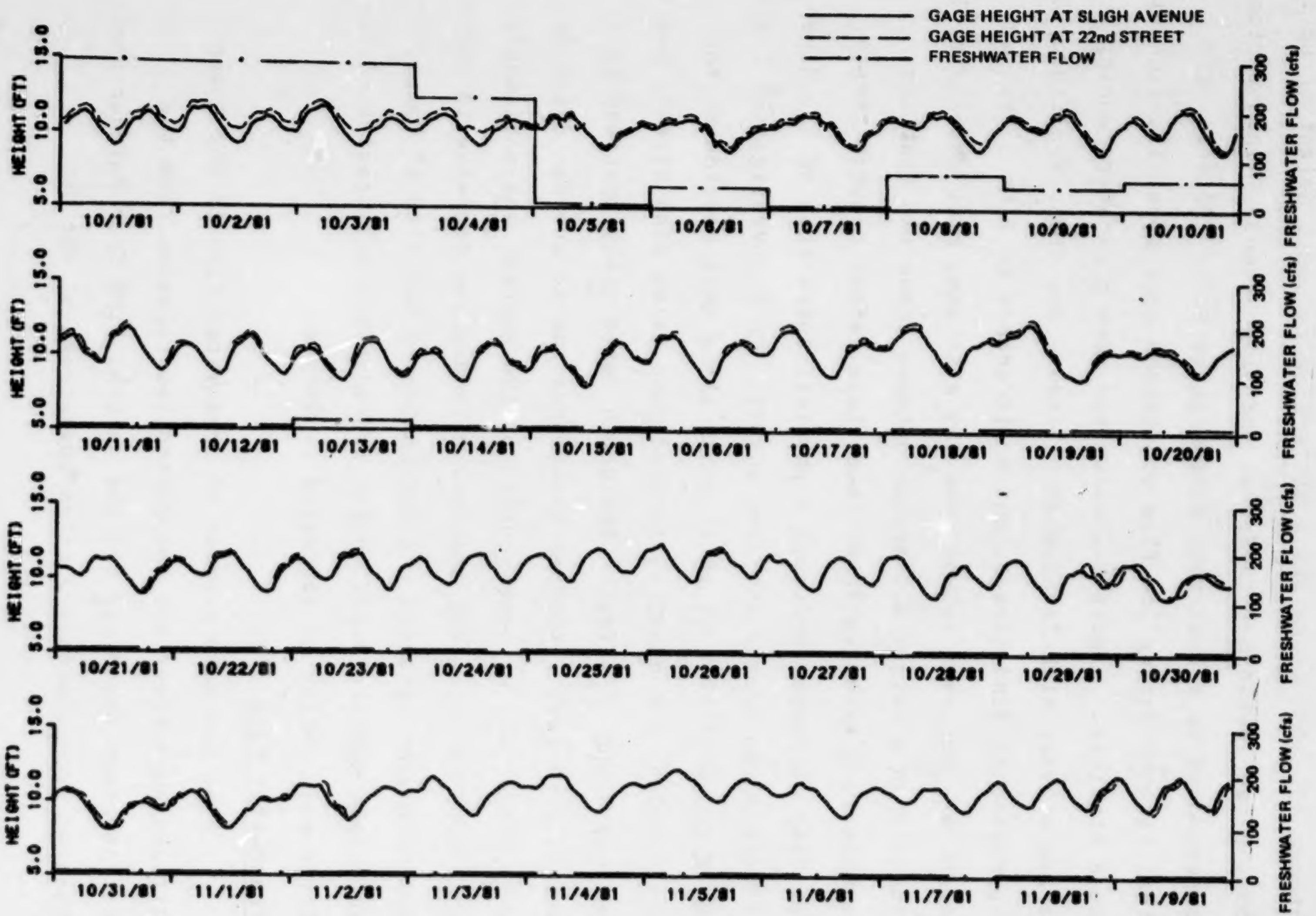


FIG. 2-3 GAGE HEIGHT AT SLIGH AVENUE AND 22nd STREET AND FRESHWATER FLOW FROM HILLSBOROUGH RESERVOIR OCTOBER - NOVEMBER, 1981

October 10, 1981 there was a difference in tidal height of up to about 2 feet between 22nd Street and Sligh Avenue. This period corresponded to a Reservoir discharge of 50 to 300 cfs. The tidal heights during low flow conditions were about the same at these stations. Figure 2-4 shows the same parameters during a period of very high freshwater release. The tidal amplitude was suppressed at 22nd Street, and a difference of 2 to 3 feet in height was observed between the two stations, most notably at low tide. Such a height difference between these two stations results in a steep water surface slope (about 0.00016 ft/ft). The City of Tampa performed a physical inspection of the River between Sligh Avenue and 22nd Street. This investigation led to the finding of several shoal areas along this section of the River. One, for example, located just below 22nd Street, has a maximum depth of 4 feet. The depth immediately upstream is in excess of 7 feet. Another shoal area has an average depth of only 3 feet and an acceleration of the current was noticeable. Four such restrictions that could impede the decrease in depth on ebb tide were observed and documented by the City of Tampa. This knowledge was important to the hydrodynamic calibration of the River model which is addressed in Chapter 4.

Freshwater Flow

The two main sources of freshwater flow to the lower Hillsborough River are the controlled releases from the Hillsborough Reservoir and the natural flow from Sulphur Springs located approximately 2 miles downstream of the Dam.

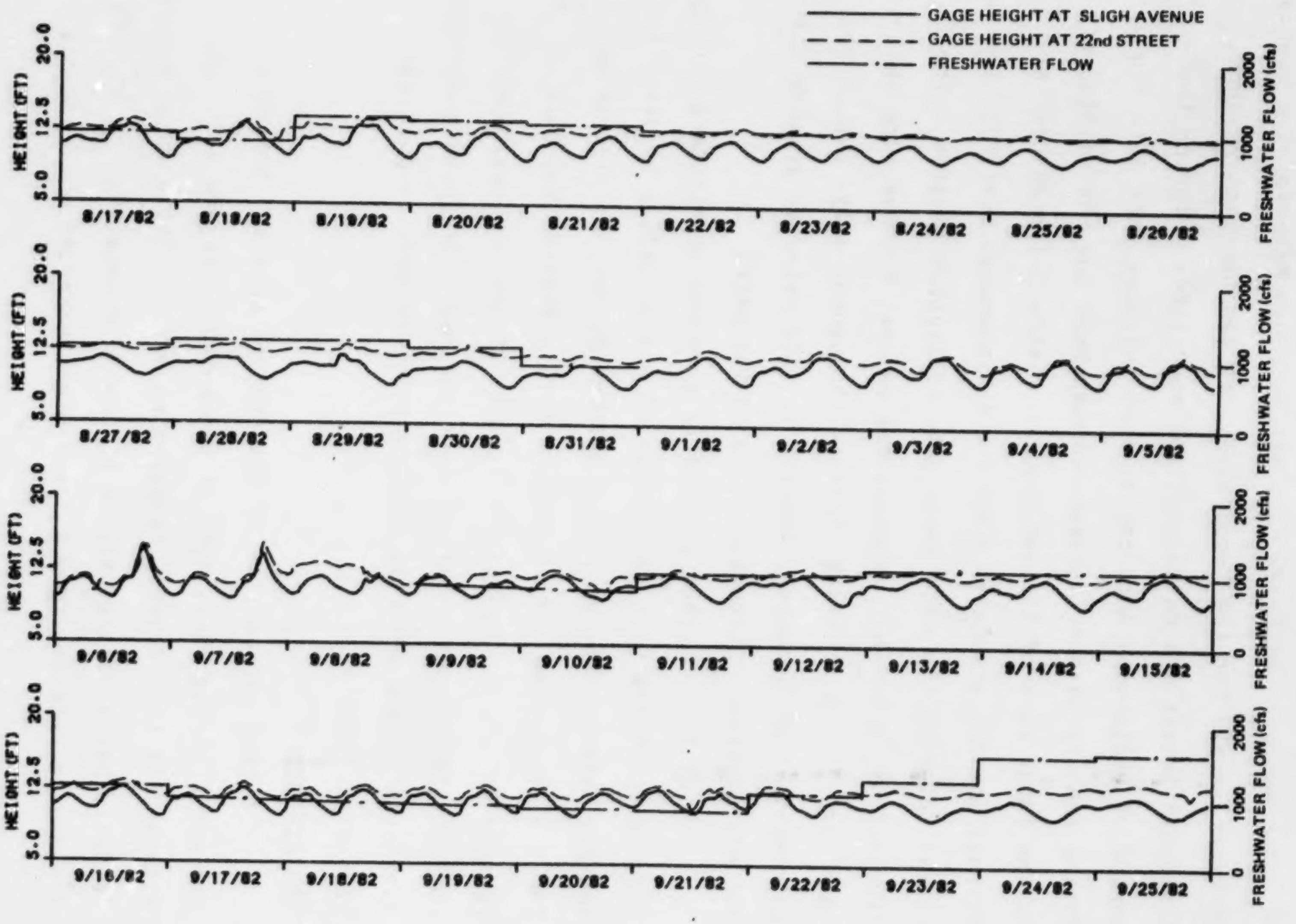


FIG. 2-4 GAGE HEIGHT AT SLIGH AVENUE AND 22nd STREET AND FRESHWATER FLOW FROM HILLSBOROUGH RESERVOIR
AUGUST - SEPTEMBER, 1982

Freshwater releases from Hillsborough Reservoir, a source of water supply for the Tampa area, are dependent on seasonal Reservoir levels and meteorological conditions. During the period of continuous data collection, releases were 0 to 100 cfs during the dry season (October through May) and 500 to 1500 cfs in the later part of the wet season. Table 2-1 presents the average monthly discharge from the Hillsborough Reservoir for the period covering the continuous data collection program. The fluctuation in monthly releases can be seen by observing that in 1981 very little flow was released throughout July, August and October through December, whereas in 1982 releases greater than 100 cfs continued throughout most of the year.

Flow from Sulphur Springs (a groundwater discharge) ranges from 10 to 60 cfs with an average of approximately 40 cfs. The monthly average discharge from Sulphur Springs is also shown in Table 2-1. During dry periods, water is pumped from Sulphur Springs to the Reservoir at a rate of 25 cfs to supplement the public water supply. During these periods, the Sulphur Springs discharge to the River is notably less, as seen in July and December, 1981.

Temperature

A time series plot of temperature at Platt Street from mid-April through May, 1982 is presented in Figure 2-5. As observed in this Figure, temperature varies little on an hourly or daily basis during periods of low to moderate (0 to 400 cfs) freshwater releases from Hillsborough Reservoir and moderate

TABLE 2-1. MONTHLY AVERAGE FRESHWATER FLOW (CFS) TO THE LOWER HILLSBOROUGH RIVER(1)

Month	Hillsborough Reservoir	Sulphur Springs
July, 1981	1.26	21.5
August	53.50	44.1
September	806.	49.6
October	44.40	43.7
November	0.65	41.4
December	0.79	17.6
January, 1982	155.	44.1
February	134.	39.9
March	174.	36.9
April	163.	41.0
May	1.57	41.3
June	200.	48.6
July	839.	47.8
August	984.	48.1
September	1,124.	46.4

1. Source: USGS

temperatures. Figure 2-6 presents a comparison between temperature and gage height at Platt Street in July and August, 1982. Freshwater releases from the Reservoir ranged from 400 to 1,600 cfs during this period. It appears that the freshwater releases were several degrees cooler than water from Hillsborough Bay since the River temperature increased as the tide rose and

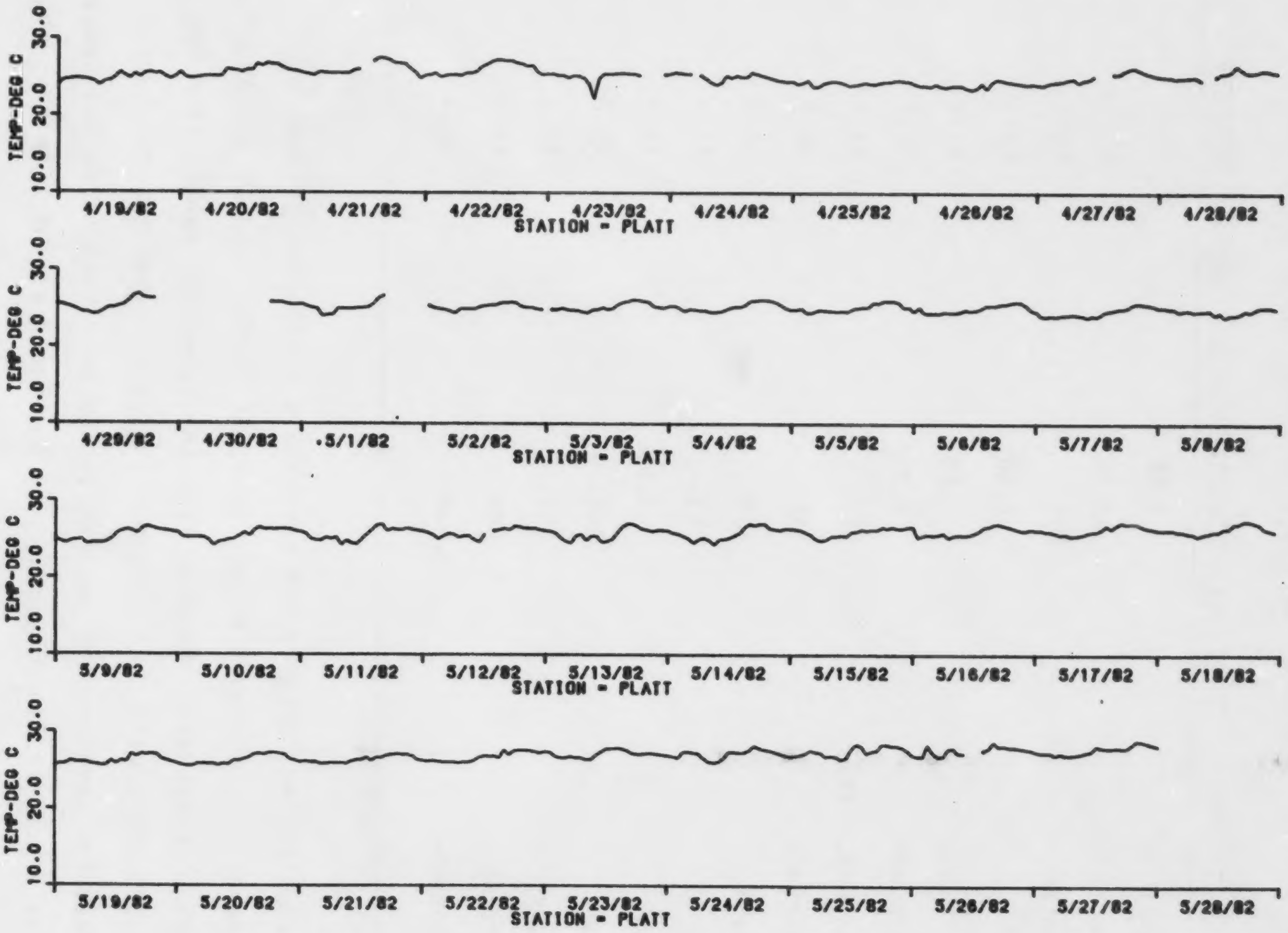


FIG. 2-5 TEMPERATURE AT PLATT STREET, APRIL-MAY, 1982

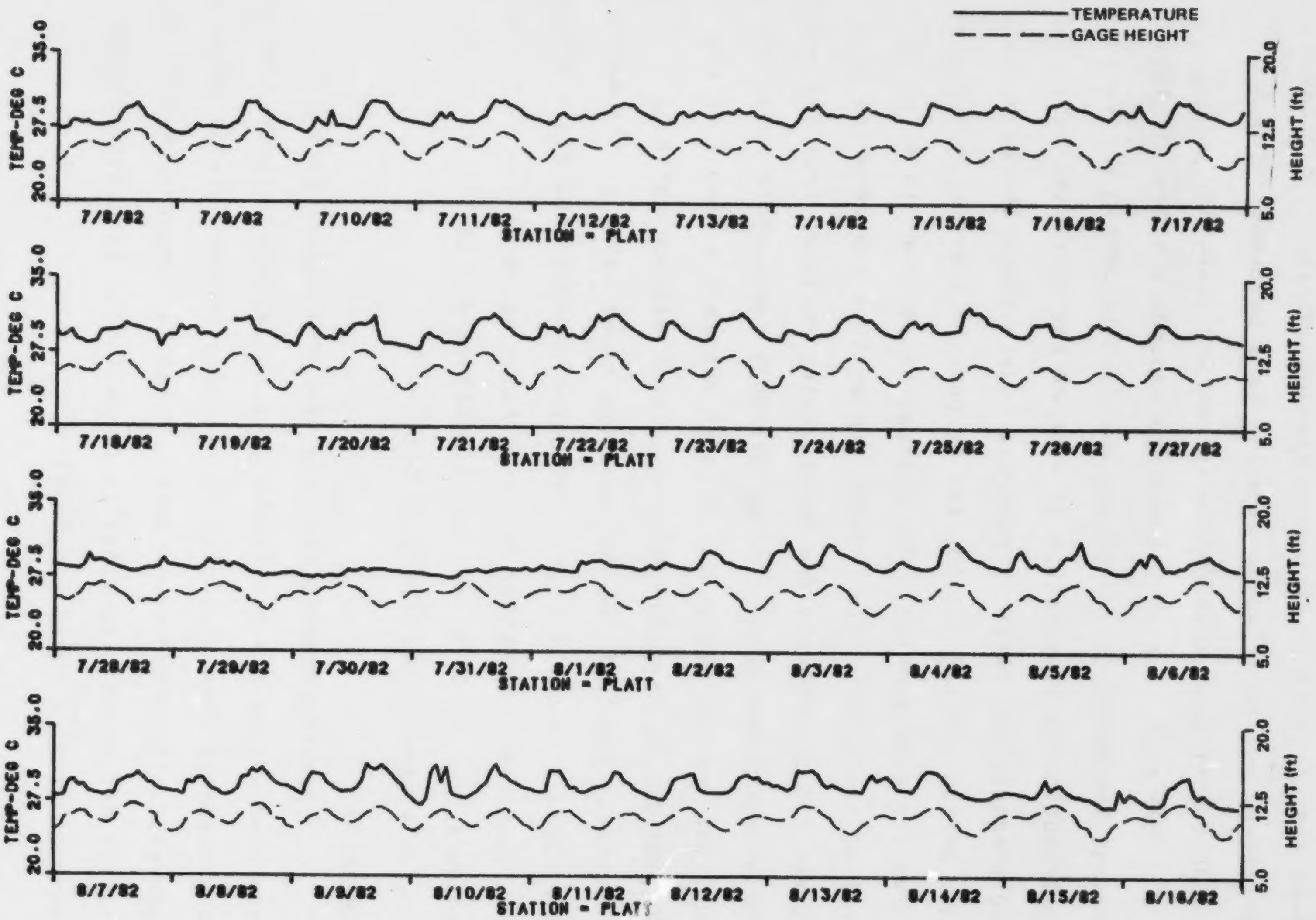


FIG. 2-6 TEMPERATURE AND GAGE HEIGHT AT PLATT STREET
JULY - AUGUST, 1982

decreased as it fell. Upstream stations exhibited similar variations but to a lesser extent. This is because the proportion of Bay water decreases heading upstream.

One full year of temperature records (October 1, 1981 through September 30, 1982) was analyzed to obtain a frequency distribution of temperature at each of the four stations. Table 2-2 presents the range of recorded hourly temperatures during this period and the 10, 50, and 90 percent exceedance temperatures for each station. The average temperature is about 25°C in most of the River. The coldest temperature was recorded at 22nd Street and is probably due to its being furthest from the warmer Hillsborough Bay water. Sligh Avenue's temperature range was the smallest for all stations. This is possibly a result of the Sulphur Springs inflow upstream of this station which is relatively constant and may cool the river water in the summer and warm it in the winter. The Columbus Drive and Platt Street stations both have about the same range of temperature, though it appears that Platt Street is slightly warmer in the winter due to its proximity to Hillsborough Bay.

Salinity

Specific conductivity was measured hourly at all four stations during the continuous data collection program. These measurements were converted to salinity concentrations using the corresponding temperature data. First, a temperature correction factor for converting specific conductivity to a 25°C standard was obtained(1) using the equation:

TABLE 2-2. SUMMARY STATISTICS OF TEMPERATURE (°C) IN THE LOWER HILLSBOROUGH RIVER

Station	Range of temperature (°C)	Percentile exceedance temperature (°C) 90%	50% (avg)	10%
Platt Street	13.5 - 32.7	18.50	25.10	29.40
Columbus Drive	12.4 - 32.1	18.27	24.70	28.69
Sligh Avenue	15.7 - 29.8	19.74	25.20	28.35
22nd Street	9.1 - 31.3	17.80	23.73	28.02

$$F = 1.66354 - .03309T + .00025T^2$$

where F = specific conductivity factor

T = water temperature (°C)

After multiplying the recorded conductivity by the factor F the salinity concentration was calculated(1) as follows:

$$S = 0.01372 + 0.52104C + 0.00392C^2 - 0.00003C^3$$

where S = salinity (ppt)

C = adjusted conductivity (mMHOS)

Figure 2-7 is a plot of tidal height, salinity and freshwater flow at Columbus Drive. This Figure illustrates that the penetration of the saline wedge is related directly to the tidal motion in Hillsborough Bay and the freshwater flow from the Reservoir. The short term (hourly) salinity variations are caused by the ebbing and flooding of the tide. River salinity rises during flood tide as Bay water moves upriver, and falls during ebb tide.

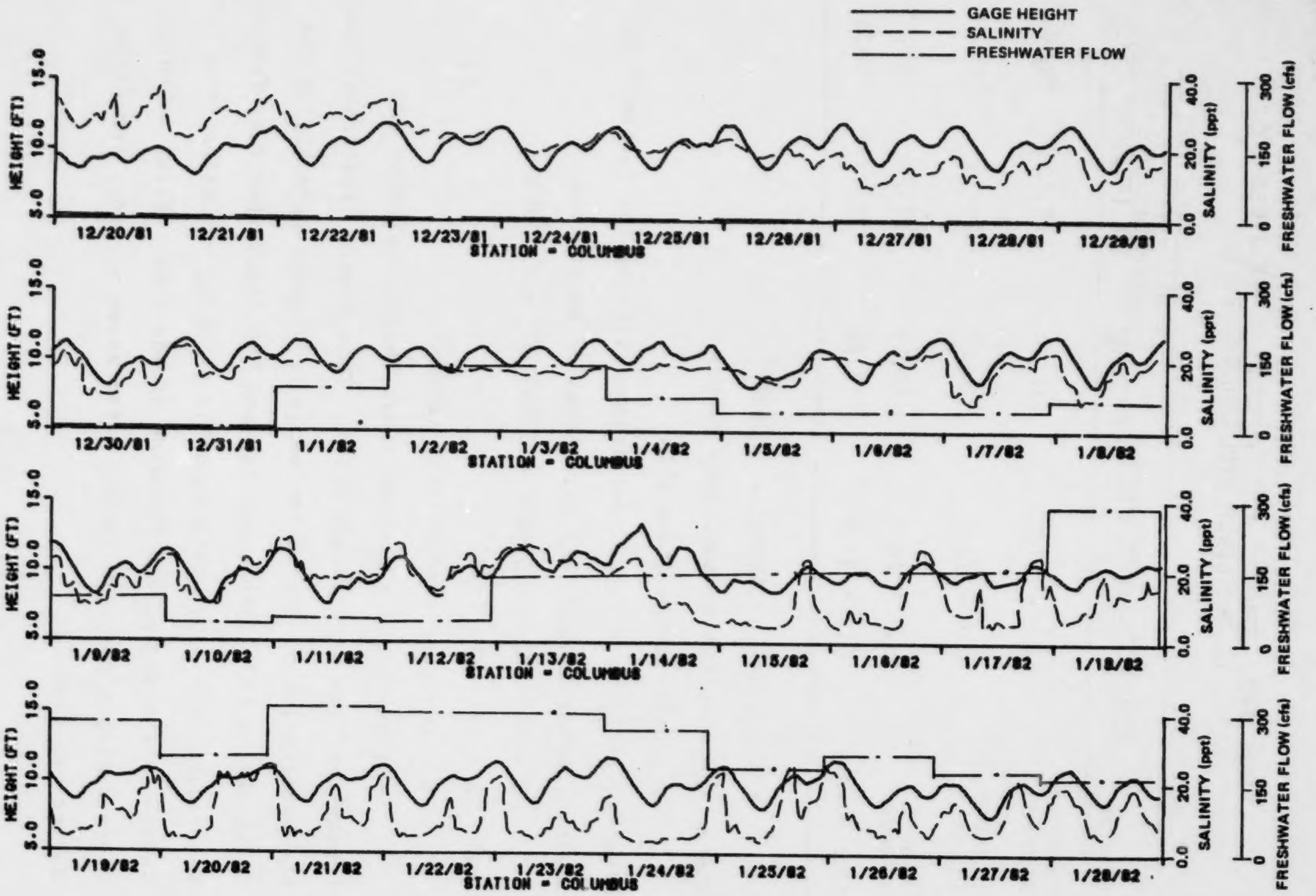


FIG. 2-7 GAGE HEIGHT, SALINITY, AND FRESHWATER FLOW AT COLUMBUS DRIVE
DECEMBER 1981 - JANUARY 1982

Long term changes in salinity are caused by freshwater discharge. Throughout December, 1981, there was essentially no discharge from the Reservoir. From December 25-27, 1981, a series of rain events occurred with a total rainfall of 2.64 inches. The stormwater runoff that entered the River after these events served to dilute the saline water, as evidenced in the Figure. In early January the freshwater flow increased to about 150 cfs, decreased for several days, then increased again. Its effect on the salinity concentrations is clearly evident as well.

The tidally-induced variation of salinity is greater at Columbus Drive during high (>400 cfs) freshwater flow periods. This is because the salinity intrudes slightly upstream of Columbus Drive.

A frequency distribution of salinity at each station was obtained for one year of record from October 1, 1981 through September 30, 1982. The results of this analysis are presented in Table 2-3. This Table shows a wide range of salinity concentrations at all four stations including the Bay boundary (Platt Street). The very low salinity concentrations reflect conditions of high freshwater flow on the order of 1,500 cfs that occurred in early and late July, 1982. The average salinity concentrations are quite low at Sligh Avenue and 22nd Street, indicating that significant saline intrusion at mid-depth in these reaches of the River is rare.

TABLE 2-3. SUMMARY STATISTICS OF SALINITY (PPT) FOR THE LOWER HILLSBOROUGH RIVER

Station	Range of Salinity (ppt)	Percentile exceedance salinity (ppt) 90%	50% (avg)	10%
Platt Street	.03 - 34.3	4.5	19.4	27.1
Columbus Drive	.09 - 38.0	2.0	13.3	24.1
Sligh Avenue	.09 - 22.5	0.3	1.9	16.4
22nd Street	.08 - 15.6	0.2	0.6	6.3

Table 2-4 presents an approximate relationship between the extent of saline intrusion in the lower Hillsborough River and freshwater discharge, as observed from the continuous data. The flow values presented in this Table agree well with those presented presented in the Phase I Report of the Tampa NURP Study(2). It should be noted, however, that the flow conditions presented in Table 2-4 correspond to saline intrusion as measured at mid-depth of the stream. Some salt water may still be present near the river bottom under these flow conditions, but the near-bottom salinity concentration cannot be determined from these data.

TABLE 2-4. SALINE INTRUSION AS A FUNCTION OF FRESHWATER DISCHARGE IN THE LOWER HILLSBOROUGH RIVER

Extent of saline intrusion	Freshwater discharge from Hillsborough River (cfs)
22nd Street	<50
Sligh Avenue	<200
Columbus Drive	<1,100

Dissolved Oxygen

Dissolved oxygen concentrations from mid-April through May, 1982 at Platt Street are shown in Figure 2-8. The DO saturation concentration, (calculated using the corresponding salinity concentrations and temperatures at each station), is also shown. A large diurnal variation in DO levels is observed from May 9 - 27, 1982. The DO values above saturation levels could indicate algal photosynthetic activity.

Figure 2-9 provides additional insight to the variations in DO concentrations. The tidal variation and DO concentrations at Columbus Drive are shown. On flood tide the DO levels generally dropped, and on ebb tide they rose. It was observed that the lowest DO concentrations occurred in the bottom layer of the saline wedge. During ebb tide the wedge travels downstream and DO levels rise.

No freshwater was released from the Reservoir from May 29 through June 23, 1982. On June 24, 1982 the Reservoir began discharging at 188 cfs, and increased to over 700 cfs on

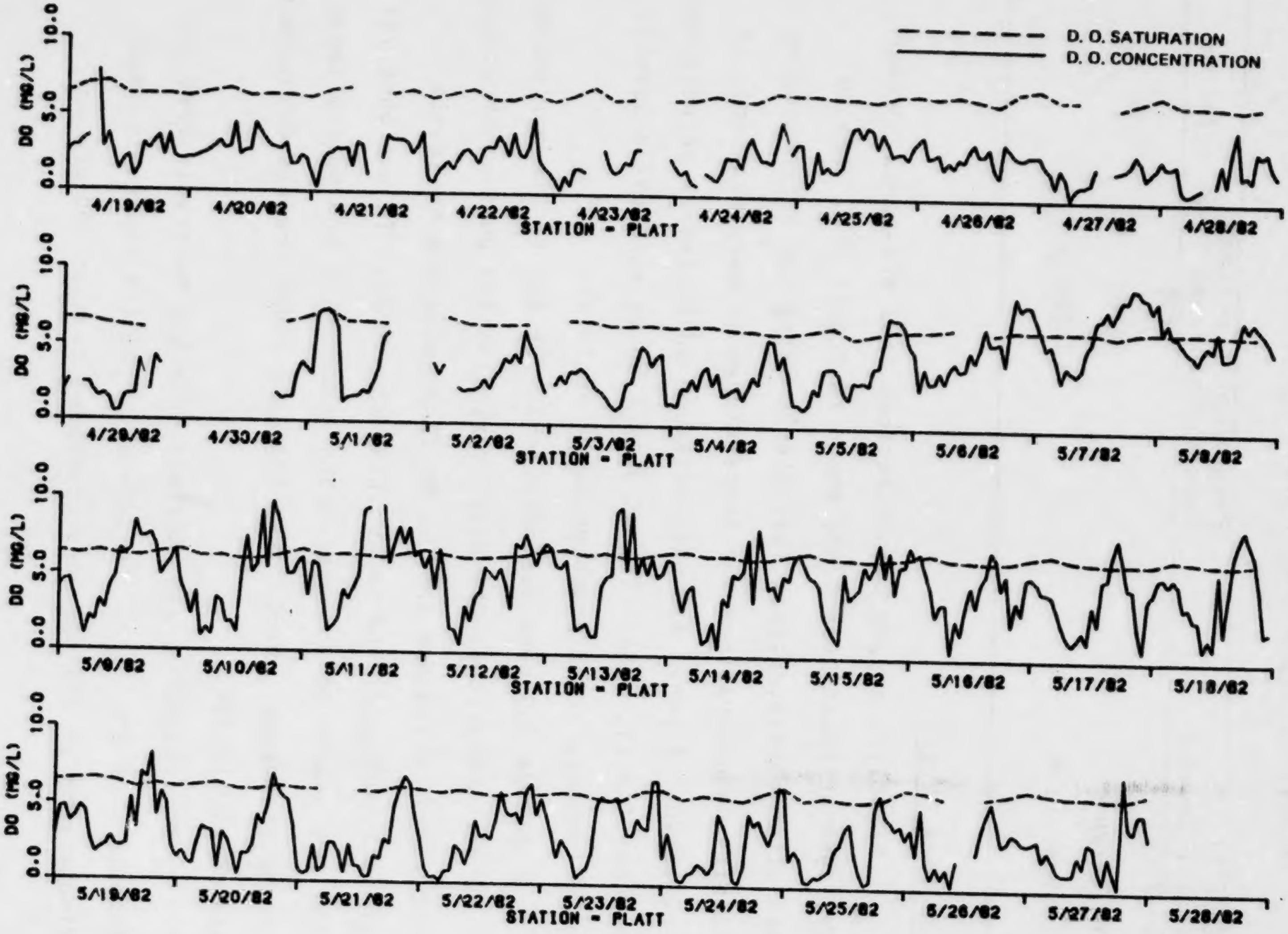


FIG. 2-8 DISSOLVED OXYGEN CONCENTRATIONS AND SATURATION LEVELS AT PLATT STREET, APRIL-MAY, 1982

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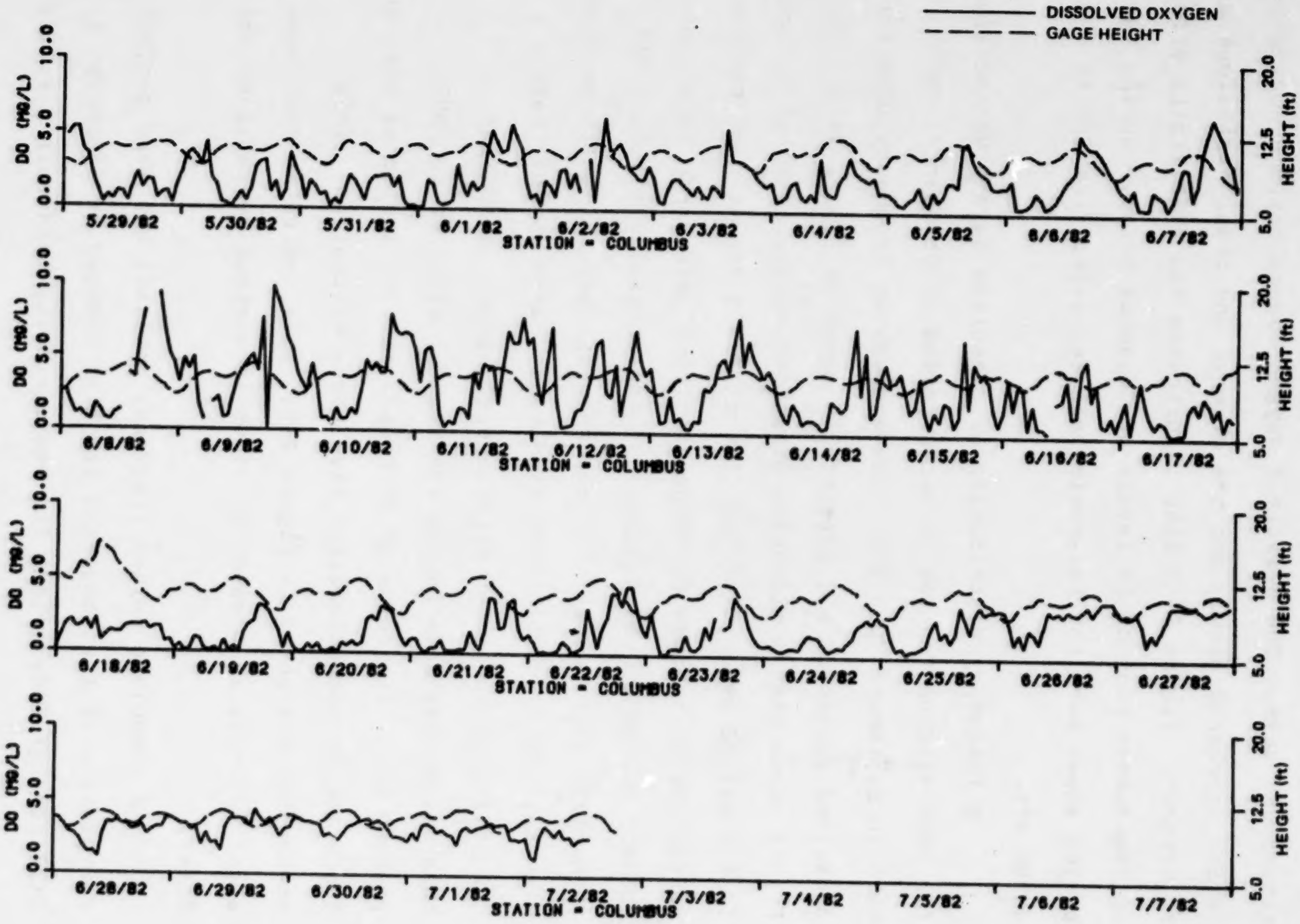

FIG. 2-9 DISSOLVED OXYGEN AND GAGE HEIGHT AT COLUMBUS DRIVE
MAY - JULY, 1982

subsequent days. The dissolved oxygen concentrations during this period increased slowly and the diurnal and tidal variations were suppressed. Figure 2-10 also illustrates the stabilizing effect of freshwater flow on DO levels at Columbus Drive. During the period shown here the Reservoir release varied from 800 to 1,200 cfs.

A frequency distribution of dissolved oxygen was obtained for each station for the 12 month period of October 1, 1981 through September 30, 1982. The exceedance frequency plot for dissolved oxygen at all stations is shown in Figure 2-11. This Figure shows that a mid-depth dissolved oxygen level of 4.0 mg/l is not met 60 percent of the time at Platt Street and that the 50 percentile or average DO concentration at mid-depth is approximately 3.6 mg/l. Statistics for the remaining stations are summarized in Table 2-5. These results indicate that the average mid-depth DO concentrations tend to decrease as one travels downstream on the lower Hillsborough River. A similar observation was made during the Phase I study of the NURP program (2). The range of DO concentrations indicates that at times the DO concentrations rise above saturation. This occurrence was noted in Figure 2-8. This indicates that some algal activity is present at times in various segments of the River.

A dissolved oxygen frequency analysis was also performed for periods of low, moderate and high freshwater discharge from Hillsborough Reservoir. The average daily Reservoir discharges

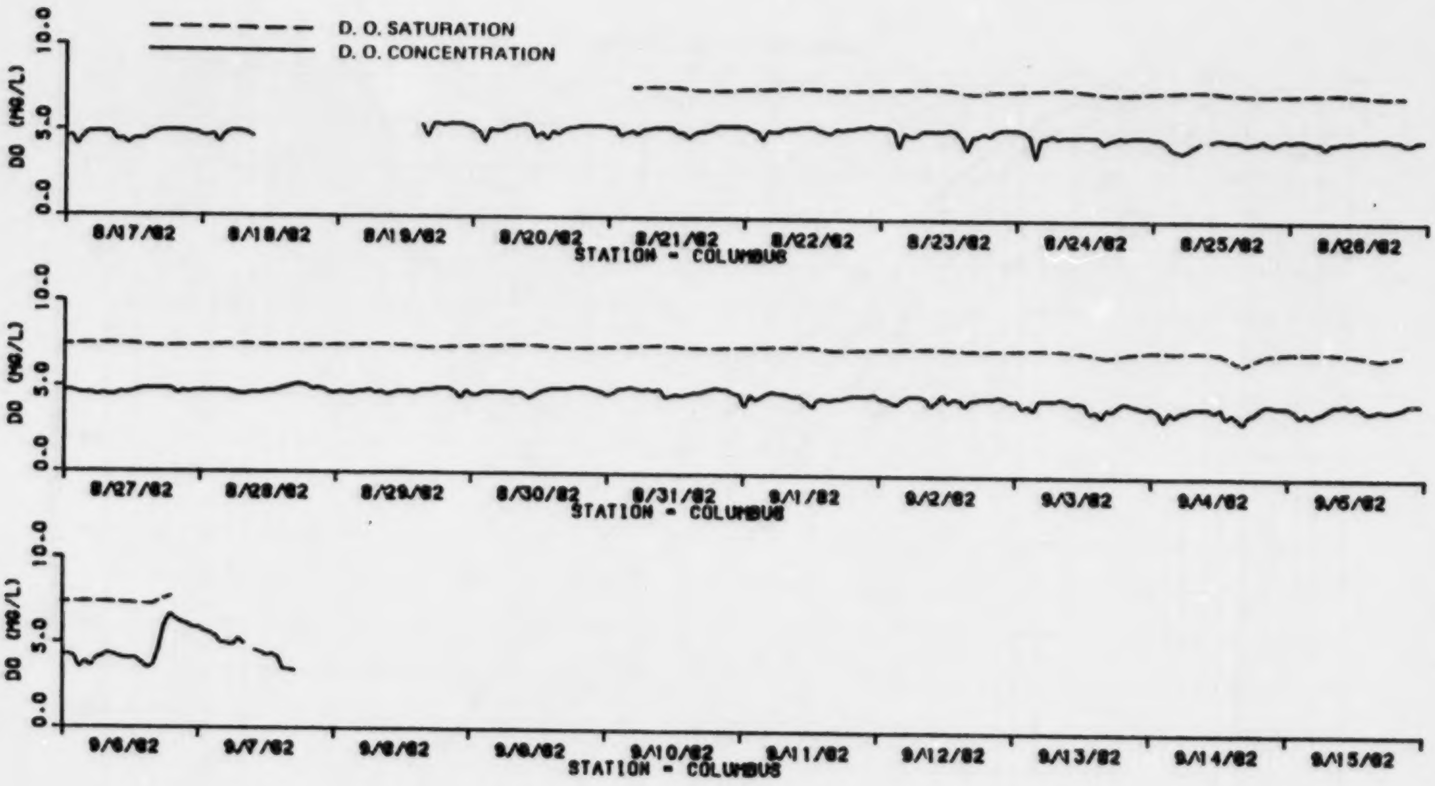

FIG. 2-10 DISSOLVED OXYGEN CONCENTRATIONS AND SATURATION LEVELS AT COLUMBUS DRIVE, OCTOBER-SEPTEMBER, 1982

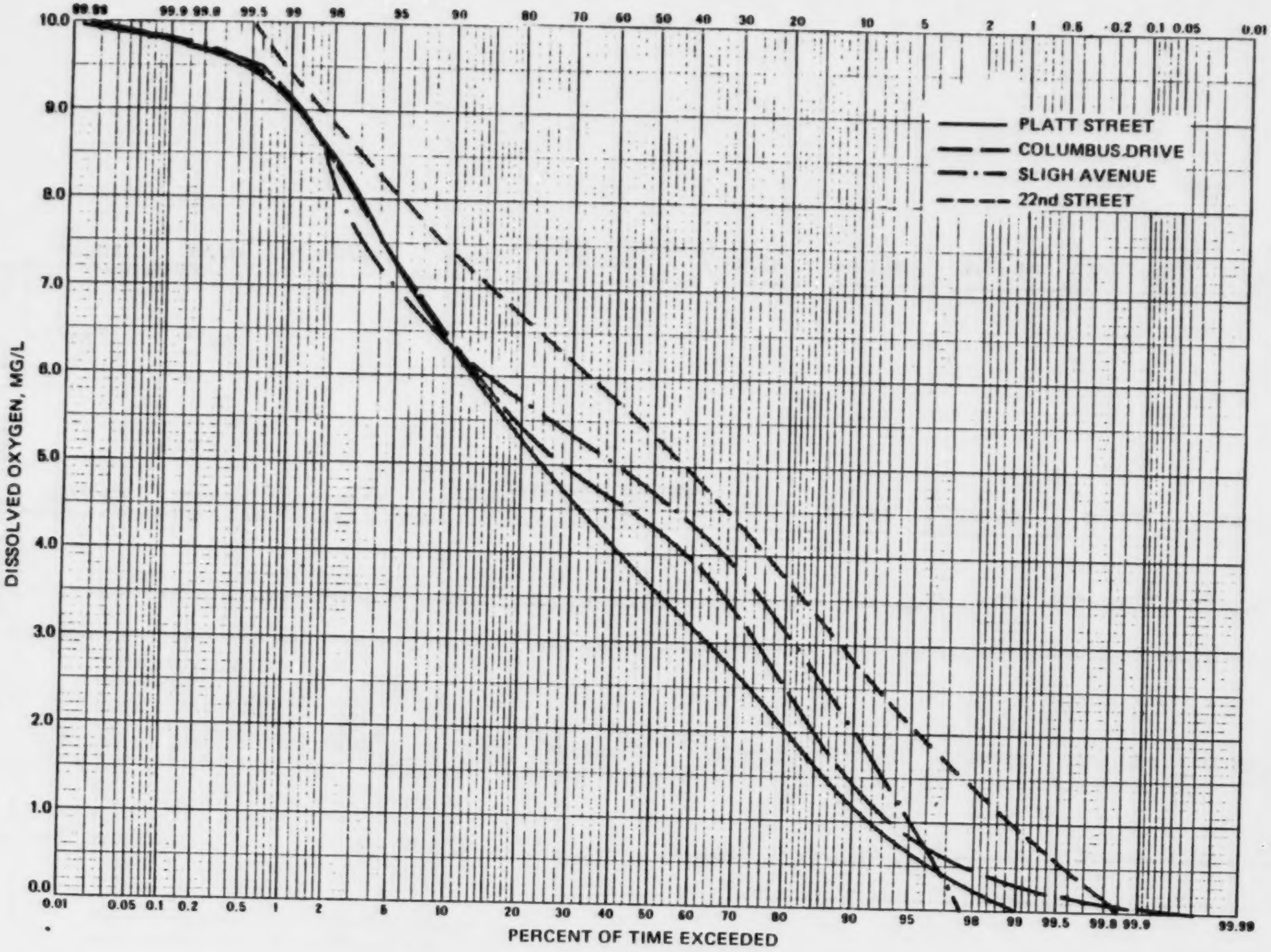

FIG. 2-11 EXCEEDANCE FREQUENCY PLOT OF DISSOLVED OXYGEN

TABLE 2-5. SUMMARY STATISTICS FOR DISSOLVED OXYGEN FREQUENCY DISTRIBUTION

Station	Range of DO concentrations (mg/l)	Average (50 percentile) DO concentration (mg/l)	Percent of time DO concentration is < 4.0 mg/L
Platt Street	0.0 - 10.0	3.6	59
Columbus Drive	0.0 - 10.0	4.3	41
Sligh Avenue	0.0 - 10.0	4.8	31
22nd Street	0.0 - 16.0	5.2	24

during the 15 month period of continuous data collection were examined. Months of low (< 10 cfs) daily freshwater discharge from the Hillsborough Reservoir were separated from those with a discharge of 10 to 400 cfs and those with discharges greater than 400 cfs. The corresponding DO data were analyzed separately.

The results of this analysis are presented in Table 2-6. During periods of low freshwater discharge the average DO levels are highest at Platt Street and lowest at Sligh Avenue where the saline penetration is prominent due to low freshwater flows. DO concentrations are usually lower in the vicinity of the saline wedge. Moderate freshwater releases (10 to 400 cfs) significantly improve average DO concentrations at Columbus Drive, Sligh Avenue and 22nd Street whereas average DO concentrations at Platt Street remain the same. Prolonged

TABLE 2-6. DISSOLVED OXYGEN STATISTICS IN THE LOWER HILLSBOROUGH RIVER AS A FUNCTION OF FRESHWATER FLOW FROM HILLSBOROUGH RESERVOIR

Station	Low freshwater release (0-10 cfs) (1)		Moderate freshwater release (10-400 cfs) (2)		High freshwater release (>400 cfs) (3)	
	Average DO concentration (mg/l)	Percent of time DO<4.0mg/l	Average DO concentration (mg/l)	Percent of time DO<4.0 mg/l	Average DO concentration (mg/l)	Percent of time DO<4.0 mg/l
Platt Street	4.1	48	4.1	47	3.0	80
Columbus Drive	3.4	59	4.7	24	4.2	40
Sligh Avenue	2.8	79	5.2	16	4.7	13
22nd Street	3.8	56	6.7	6	5.2	5

1. October, November, December, 1981; May, June, 1982.
2. January through April, 1982.
3. July through September, 1982.

freshwater discharges greater than 400 cfs result in very low DO concentrations at Platt Street. The high freshwater flows limit the saline penetration to this region. The average DO concentrations at Columbus Drive, Sligh Avenue and 22nd Street are slightly lower during high freshwater flow than moderate flows though violations of the State standard of 4.0 mg/l are less frequent. Reservoir water is usually released from the lower gates of the Dam during high freshwater flows. Low DO concentrations in the bottom waters of the Reservoir may lower overall DO concentrations in the River during these periods. Resuspension of bottom material during high-freshwater releases may also affect the overall DO levels at these stations.

A moderate (10 to 400 cfs) freshwater discharge from the Reservoir has a positive effect on most of the River, raising average DO concentrations by 1 to 2 mg/l and significantly reducing the violation of the State's DO standard.

The dissolved oxygen concentrations in the lower Hillsborough River are lowest at the upstream end of the saline wedge. For example in Table 2-6, the wedge has penetrated to Sligh Avenue for releases less than 10 cfs. The lowest DO concentrations also occur at Sligh Avenue. Under high freshwater releases the saline wedge moves downstream and the low DO's occur at Platt Street.

As described in the Phase I Report (2), the estuarine circulation pattern in the lower River is such that fresh water flows downstream and the denser saline water moves upstream near the bottom of the water column. The net upstream movement of the bottom layer, in combination with the large sediment oxygen demand in the lower River, most likely cause the observed DO sag to occur at the upstream end of the saline intrusion.

It should be noted that the continuous data were collected only at mid-depth. In subsequent Chapters, the vertical variations of salinity and DO are analyzed. This leads to further understanding of the observed salinity and DO variations in the lower River.

Stormwater Runoff

The short and long term impacts of stormwater runoff on the water quality of the lower Hillsborough River are also of interest. Several storms that occurred during the continuous data collection program were selected and their effect on DO and salinity concentrations was studied at the four stations. Table 2-7 presents these storms and their impacts on DO and salinity at the four sampling stations. These storms were chosen because they occurred at a time when the freshwater discharge from the Reservoir was relatively constant over a period of days. Thus the observed water quality changes should not be attributable to changes in freshwater flow.

The available data in Table 2-7 provide some interesting observations. During periods of low freshwater flows the DO levels tend to increase at Sligh Avenue and 22nd Street stations after a storm event and either do not change or decrease slightly at the Columbus and Platt stations. The salinity at all stations

TABLE 2-7. SUMMARY OF SELECTED RAIN STORM IMPACTS ON DO AND SALINITY IN LOWER HILLSBOROUGH RIVER

Date of storm	Total rainfall (in.)	Reservoir Discharge (cfs)	Dissolved Oxygen				Salinity			
			Platt Street	Columbus Drive	Sligh Avenue	22nd Street	Platt Street	Columbus Drive	Sligh Avenue	22nd Street
Dec. 25-27, 1982	2.64	0.70	-(1)	-	-	increase	slight decrease	decrease	decrease	decrease
April 11, 1982	0.83	379.	no change	no change	no change	no change	slight decrease	slight decrease	no change	no change
May 30-31, 1982	3.24	1.5	-	no change	increase	-	-	decrease	decrease	decrease
June 2-3, 1982	2.20	134.	slight decrease	no change	decrease	-	no change	slight decrease	no change	no change
June 17-18, 1982	4.07	1.3	slight decrease	slight decrease	-	increase	slight decrease	decrease	slight decrease	decrease
July 7, 1982	3.38	646.	no change	-	no change	-	no change	-	no change	no change

(1) Insufficient data.

decreases after storms during low freshwater flow periods. The flushing provided by the stormwater runoff is significant enough to dilute the salinity and improve the DO in the stagnant upstream areas.

During periods of moderate to high freshwater flows the four stations exhibit little or no change in DO or salinity concentrations after a rain storm. The Reservoir releases alone tend to reduce the salinity concentrations as discussed earlier. It appears that the impact of stormwater runoff is insignificant in such cases, and DO levels are not affected significantly. In no case was there a clearly identifiable DO sag caused by these storm events.

Summary

The freshwater release from the Hillsborough Reservoir to the lower Hillsborough River plays a crucial role in the water quality of the River. The absence of these releases results in saline water penetrating to 22nd Street. This tends to reduce dissolved oxygen levels in the upper reaches of the River. Moderate freshwater releases from the Reservoir (100 to 500 cfs) push the saline wedge downstream of Sligh Avenue. Dissolved oxygen concentrations improve upstream of the wedge and algal activity is suppressed. Freshwater flows around 1000 cfs further move the salinity intrusion down to Platt Street and improve the dissolved oxygen concentrations in the upper reaches of the River, but have a negative effect on DO levels near the mouth of the River. The lowest DO concentrations occur at the upstream end of the saline wedge.

Stormwater runoff plays a minor role in terms of affecting DO levels in the River. During periods of low freshwater releases the stormwater runoff appears to improve DO levels due to increased flow. During periods of moderate to high freshwater releases, stormwater runoff appears to have no impact on any of the parameters measured during the continuous data collection program.

REFERENCES

1. Hydrolab Corporation, Operation and Maintenance Instructions, June, 1981

2. Metcalf & Eddy, Inc., Phase I - Receiving Water Study, City of Tampa, Tampa Nationwide Urban Runoff Program Study, December, 1981.

CHAPTER 3

SYNOPTIC DATA

General

In a tidally affected estuary such as the lower Hillsborough River, depths of flow, magnitude and direction of current, salinity, temperature, and water quality concentrations vary continuously during each tidal cycle. Time histories of variation of these parameters are essential to determine the cause and effect relationships among them. During dry weather, variations of these parameters would be due to tides, waste loads already present in the water column as well as in the bottom deposits, and advective flows from upstream, if any. During wet weather, variations of these parameters would, in addition, be affected by stormwater flows and loads discharged into the lower River.

Several synoptic surveys were conducted during this study. Synoptic surveys are intensive field surveys designed to evaluate the short-term (inter-tidal) variations of water quality in the lower Hillsborough River. The data are collected at several stations (several depths per station), several times per day.

In this Chapter, the synoptic survey data are analyzed to evaluate conditions in the lower River. The purpose of these measurements was to test water quality conditions under different hydrologic conditions to compare their impact on water quality.

In particular, an evaluation of the effect of stormwater on the lower River was desired. The data are used to supplement the continuous data analyzed in Chapter 2. Finally, these measurements are used to calibrate and verify the hydrodynamic and water quality river/estuary model as presented in Chapter 4.

Synoptic Field Surveys

Five synoptic surveys were conducted in the lower Hillsborough River. The surveys are summarized in Table 3-1. The surveys were designed to collect data during the following conditions:

1. A dry weather period with no freshwater flow.
2. A dry weather period with intermediate freshwater flow.
3. A dry weather period with large freshwater flow.
4. Before, during and after a storm event with no freshwater flow.
5. Before, during and after a storm event with high freshwater flow.

The data from these programs are used to evaluate the impact of stormwater on the lower River. In addition, the effect of freshwater flow from upstream can be demonstrated.

During each survey, data were collected at four stations. These were the same stations as used for the continuous data collection, as were shown in Figure 2-1. A summary of the types and frequencies of data collected during each program is given in Table 3-2.

TABLE 3-1. LOWER HILLSBOROUGH RIVER SYNOPTIC SURVEYS

Date	Survey length (days)	Hillsborough Reservoir release (cfs)	Rainfall (inches)	Purpose	Conducted by
9/11/81	1/2	1000	-	dry weather high freshwater flow	USGS, City of Tampa
4/29 - 30/82	1	120	-	dry weather moderate freshwater flow	USGS, City of Tampa
11/4 - 7/82	3	300-500	1.5	wet weather high freshwater flow	Mote Marine Lab, Inc.
2/1 - 4/83	3	0	3.6	wet weather no freshwater flow	Mote Marine Lab, Inc.
5/16 - 17/83	1	0	-	dry weather no freshwater flow	Mote Marine Lab, Inc.

Field crews occupied each station for the entire time of the survey. Tidal height measurements were obtained from continuous recording tidal gages at intervals of 15 minutes at each station. Vertical profiles of stream velocity, temperature, dissolved oxygen and conductivity were taken at several depths at mid-stream. Samples for BOD_5, total suspended solids and fecal and total coliform were taken every 4 to 6 hours at all four stations. Additional water samples were composited over 18-hour periods and analyzed for nutrients, chlorophyll a and metals.

TABLE 3-2. DATA COLLECTED DURING SYNOPTIC SURVEYS

Data type	Method of collection	Interval of collection	Location of collection	Parameters
Tide	Continuous Recording Gage	15 minutes	4 stations	
Vertical Profile	Profiling meters	30 minutes-4 hours	4 stations, 3-5 depths	Velocity Temperature Conductivity DO
Water Quality	In-situ grabs	4-6 hours	4 stations surface and bottom	BOD_5 TSS Fecal Coliform Total Coliform
Water Quality	In-situ grabs	4-6 hours composited every 18 hours	4 stations composite of surface, mid-depth and bottom	BOD_5 COD TKN NO_2-N NO_3-N NH_3-N PO_4-P Total P TSS VSS Chlorophyll a Aluminum Copper Lead Zinc

Water quality samples were also obtained at Sulphur Springs during some of the surveys.

Synoptic Field Program Results

In this section, the data from each synoptic survey are presented and evaluated. Conclusions are then drawn regarding the lower River and its significant processes and interactions.

Dry Weather-High Flow. This survey extended from 7:00 AM to 8:30 PM on September 11, 1981. The freshwater discharge from the Hillsborough Reservoir was about 1,000 cfs and from Sulphur Springs about 50 cfs. This high flow had been occurring since the beginning of the month.

The downstream tidal variation is indicated on Figure 3-1. The survey began at flood tide and ended at ebb tide. Due to the large freshwater discharge, salinities were zero at 22nd Street and Sligh Avenue, and very low at Columbus Drive. As shown in Figure 3-2, only at the end of flood tide is there significant salinity at Columbus Drive. The salinity at Platt Street drops quite low at the end of the ebb tide with the most downstream movement of the freshwater flow.

The depth averaged DO concentrations are shown in Figure 3-3. These indicate a steady decrease as one moves downstream towards Hillsborough Bay. The variation in DO concentration is affected by salinity. At Columbus Drive, the increase in salinity coincides with a decrease in DO at the end of flood tide. The DO at Platt Street does not increase until the end of ebb tide, when the fresh water moves downstream and the salinity decreases. The low DO concentrations therefore occur in the saline water.

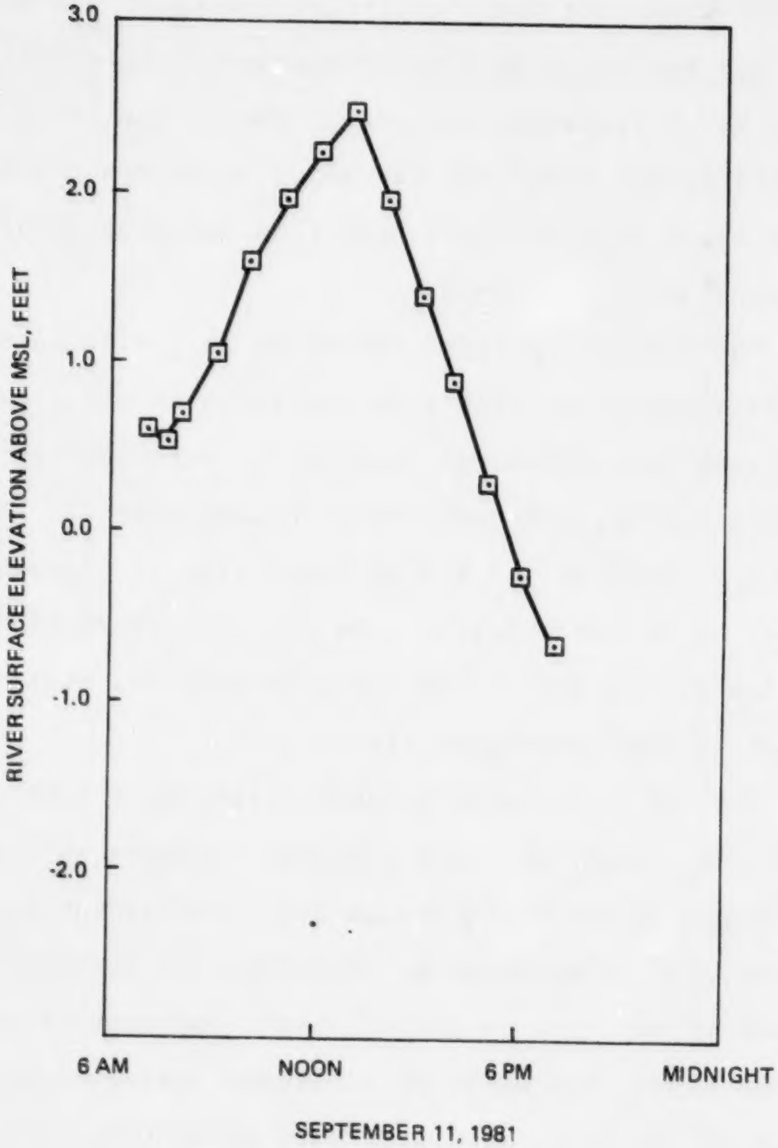

FIG. 3-1 TIDAL HEIGHT AT PLATT STREET - SEPTEMBER 11, 1981

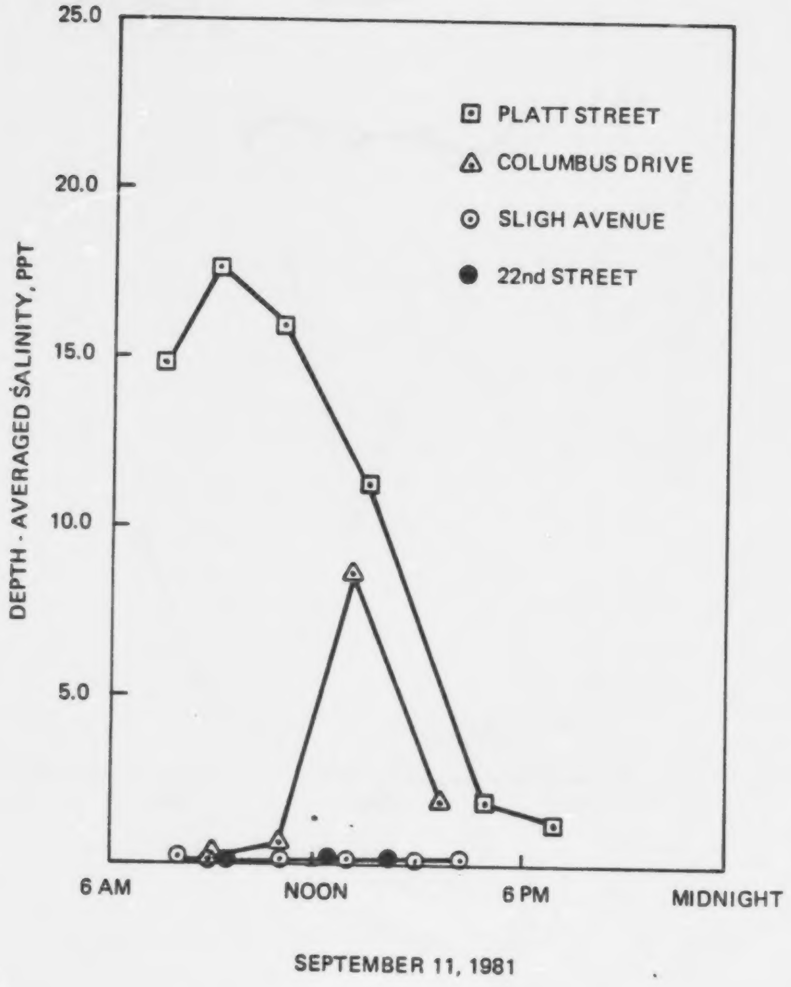

FIG. 3-2 DEPTH - AVERAGED SALINITY CONCENTRATIONS - SEPTEMBER 11, 1981

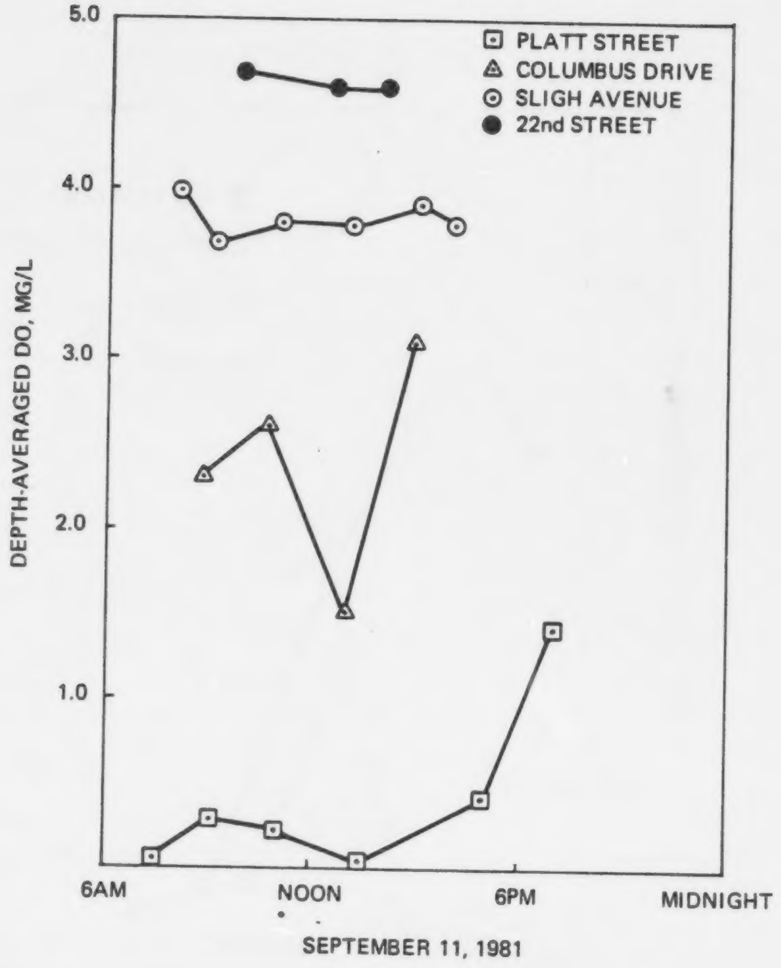

FIG. 3-3 DEPTH-AVERAGED DISSOLVED OXYGEN CONCENTRATIONS
SEPTEMBER 11, 1981

The range of concentrations for various water quality parameters measured during this survey are given in Table 3-3. BOD_5 is very low throughout the River, nitrates and nitrites are very low and remaining nutrient concentrations increase as one progresses downstream. The source of higher concentrations downstream is probably Hillsborough Bay, which was characterized as having high nutrient concentrations in the Phase I Report of the NURP Study(1).

TABLE 3-3. CONCENTRATION RANGES FOR PARAMETERS MEASURED IN THE SEPTEMBER 11, 1981 SURVEY

Parameter	Range of measured concentrations	Comment
BOD_5 (mg/l)	1.7 - 2.8	Similar range at all stations.
COD (mg/l)	21.5 - 105.7	Decreases downstream.
Organic N (mg/l)	0.80 - 1.36	Similar range at 22nd, Sligh and Columbus; lower at Platt Street
NO_3-N (mg/l)	0.001 - .940	Highest at Sulphur Springs and Sligh Avenue.
NO_2-N (mg/l)	0.000 - 0.019	Highest at Sulphur Springs; Very low (<.003 mg/l) at all other stations.
NH_3-N (mg/l)	0.004 - 0.770	Increases downstream.
PO_4-P (mg/l)	0.16 - 0.78	Increases downstream.
P (mg/l)	0.18 - 0.84	Increases downstream.
TSS (mg/l)	5.0 - 71.0	Increases downstream.

Dry Weather-Intermediate Flow. A 25-hour survey was performed on April 29 and 30, 1982 during dry weather with a freshwater discharge of about 120 cfs from the Reservoir and 48 cfs from Sulphur Springs. During the month of April prior to the survey, flows were generally above 100 cfs until April 21, after which they decreased.

The tidal variation which occurred during the survey is shown in Figure 3-4. The tide was diurnal with a range of about 3.5 feet. The variations of salinity throughout the survey at each station are shown in Figure 3-5. The saline water penetrated to Sligh Avenue but depth-averaged data are not available at that station due to instrument error. Increases in salinity correspond to flood tide and decreases to ebb tide.

The time variation of DO and BOD_5 concentrations is presented in Figures 3-6 and 3-7. The DO concentrations were high at 22nd Street, and lowest at Sligh Avenue. The DO concentrations were slowly increasing at Sligh Avenue which may be due to the input of fresh water just mentioned. It is interesting to note that the DO concentrations at Columbus Drive and Platt Street could be affected by diurnal variations due to both tide and photosynthesis. Because no data on algal activity were available during this survey, the interaction of these effects can not be identified. A trend of reducing BOD_5 appears to occur, although it is not clear whether this may be due to algal activity or to the fact that the two days prior to the survey had no flow from the Reservoir.

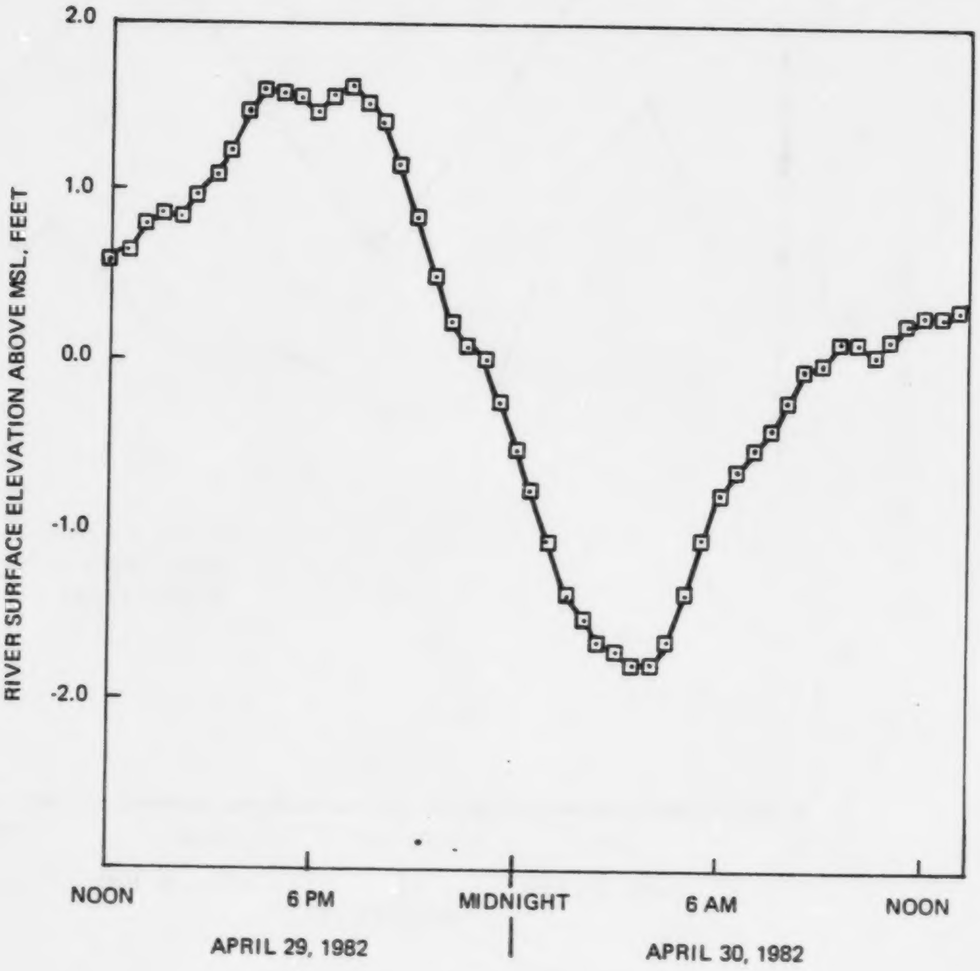

FIG. 3-4 TIDAL HEIGHT AT PLATT STREET - APRIL 29-30, 1982

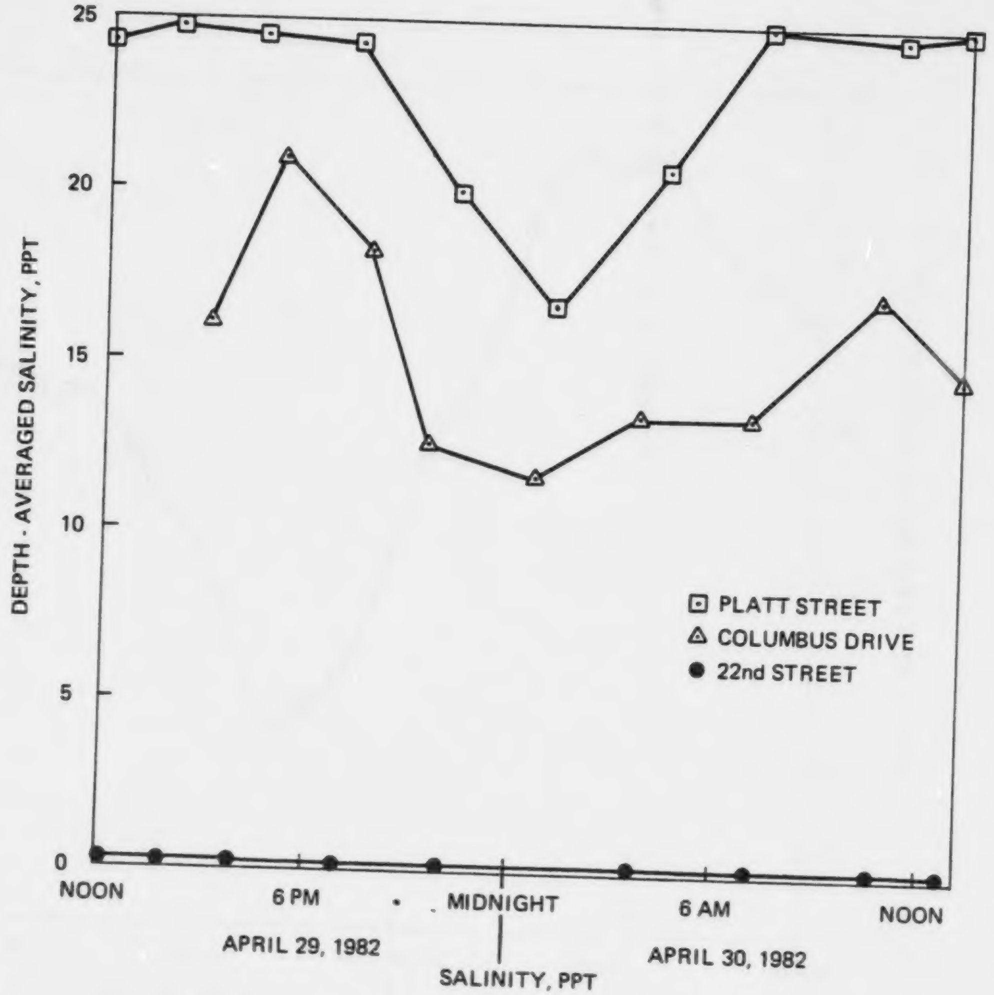

FIG. 3-5 DEPTH - AVERAGED SALINITY CONCENTRATIONS - APRIL 29-30, 1982

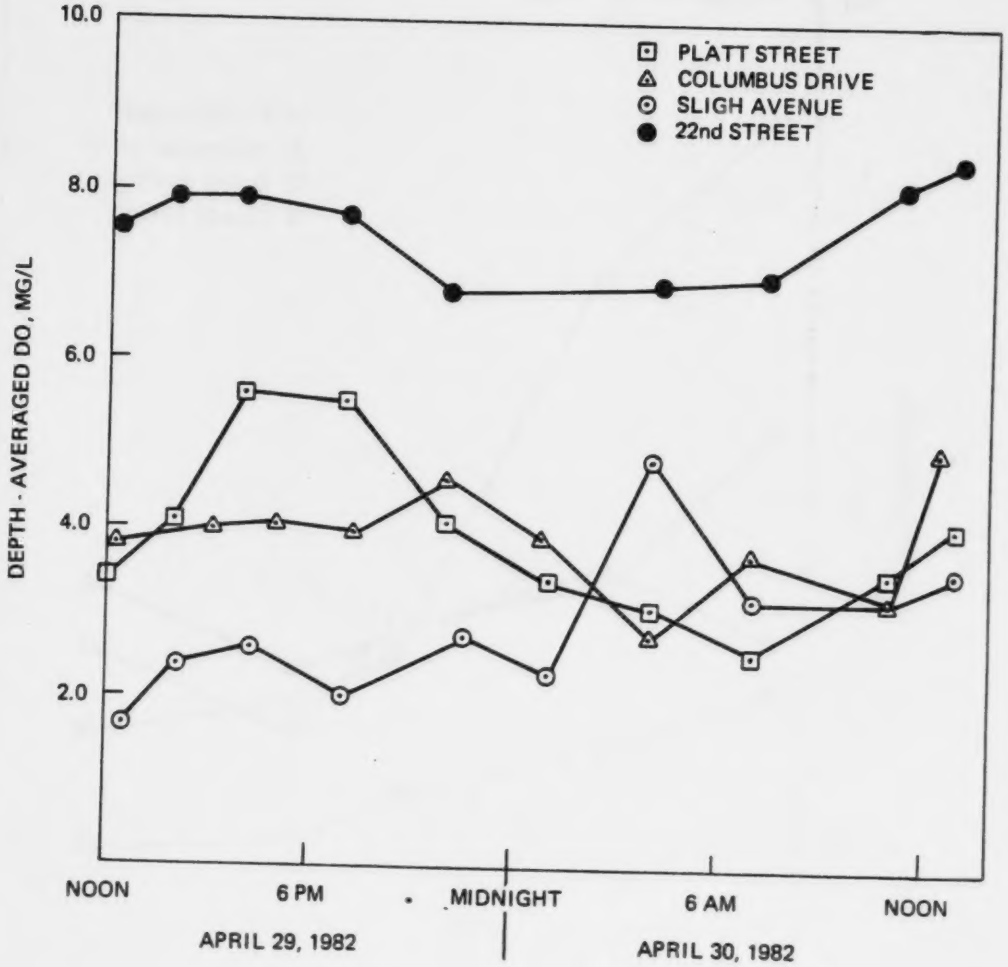

FIG. 3-6 DEPTH - AVERAGED DISSOLVED OXYGEN CONCENTRATIONS
APRIL 29-30, 1982

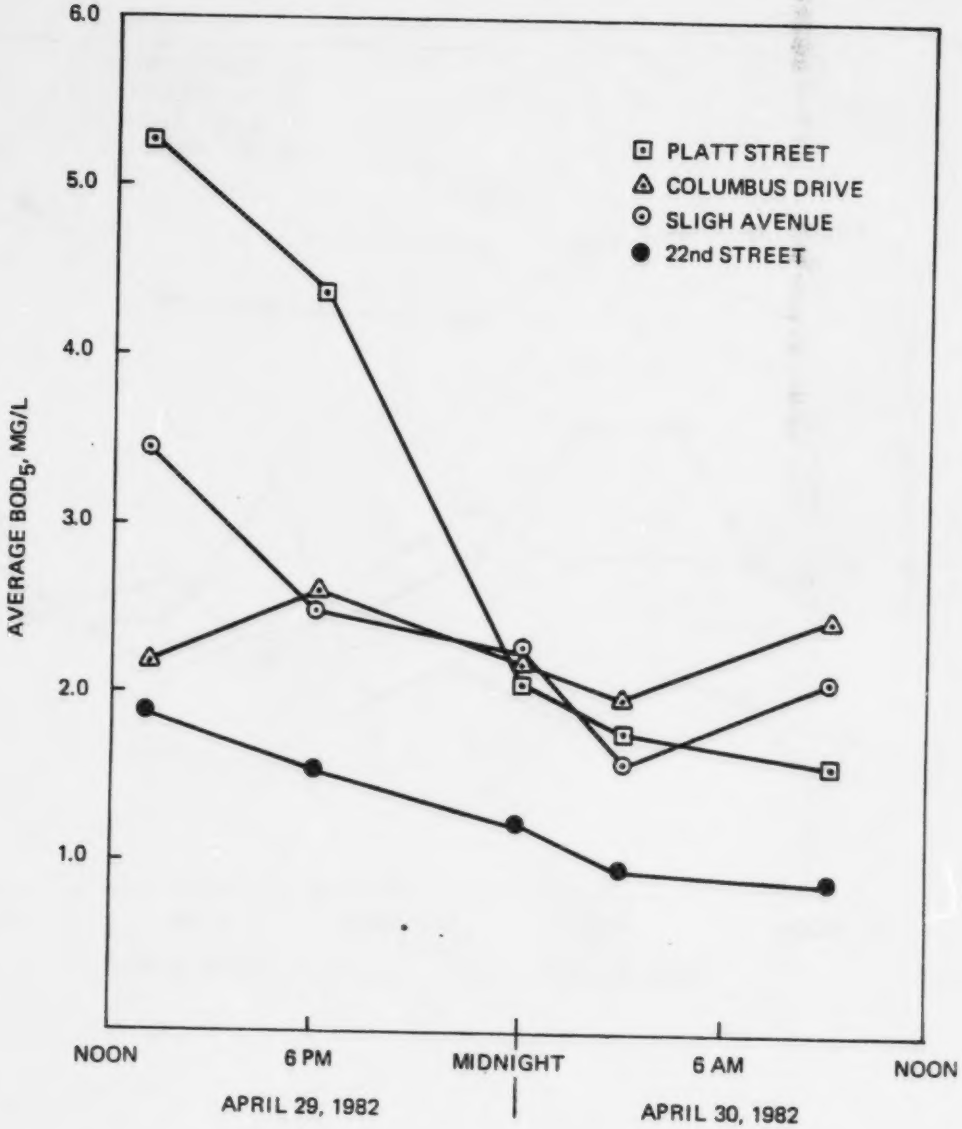

FIG. 3-7 AVERAGE BOD_5 CONCENTRATIONS - APRIL 29-30, 1982

TABLE 3-4. CONCENTRATION RANGES FOR PARAMETERS MEASURED IN THE APRIL 29-30, 1982 SURVEY

Parameter	Range of measured concentrations	Comment
COD (mg/l)	4.5 - 63.3	Highest at 22nd Street; decrease downstream.
Organic N (mg/l)	0.38 - 3.30	Increase downstream.
NO_3-N (mg/l)	0.007 - 0.297	No apparent pattern.
NO_2 (mg/l)	0.000 - 0.022	Increase downstream.
NH_3-N (mg/l)	0.032 - 0.493	Low at 22nd Street; same range for other stations.
PO_4-P (mg/l)	0.15 - 0.93	Increase downstream.
P (mg/l)	0.15 - 0.95	Increase downstream.
TSS (mg/l)	1.0 - 69.0	Increase downstream.
Aluminum (ug/l)	50 - 530	High at 22nd; same range at other stations.
Copper (ug/l)	3 - 6	Same range at all stations.
Lead (ug/l)	4 - 26	High at Columbus; same range at other stations.
Zinc (ug/l)	20 - 90	Low at 22nd and Sligh Ave.; higher at Columbus and Platt.
Fecal Coliform (MPN/100 ml)	40 - 380	Increase downstream.
Total Coliform (MPN/100 ml)	300 - 5,600	Increase downstream.

Table 3-4 identifies concentration ranges of the other parameters measured during the survey. In general, nutrient concentrations increase downstream as noted in the September 1981 survey. The ranges of nutrient concentrations are also very similar to those of the September 1981 survey. Aluminum concentrations are highest at 22nd Street and drop significantly at the other stations. Lead is highest at Columbus Drive and zinc is highest in the downstream reaches. Both fecal and total coliform counts are low upstream and increase in the downstream reaches.

Storm Event - High Freshwater Discharge. This survey covered a 72 hour period on November 4-7, 1982 with freshwater discharges from the Reservoir varying from 300 to 500 cfs. About 0.7 inches of rain fell immediately prior to the commencement of the survey. Eight hours later an additional 0.6 inch of rain was recorded. A plot of the tidal variation at Platt Street and freshwater discharge from the Reservoir is presented in Figure 3-8. Saline water was present only at Columbus Drive and Platt Street since the upstream stations were well-flushed by the freshwater discharge.

The time varying, depth-averaged salinity, DO, and BOD_5 concentrations are presented in Figures 3-9, 3-10 and 3-11, respectively. The pattern of salinity variation is clearly related to the tide. Under this freshwater flow, only Platt Street and Columbus Drive are influenced by salinity intrusion. The rainfall and increased discharge from Hillsborough Reservoir cause salinities to decrease at Columbus Drive.

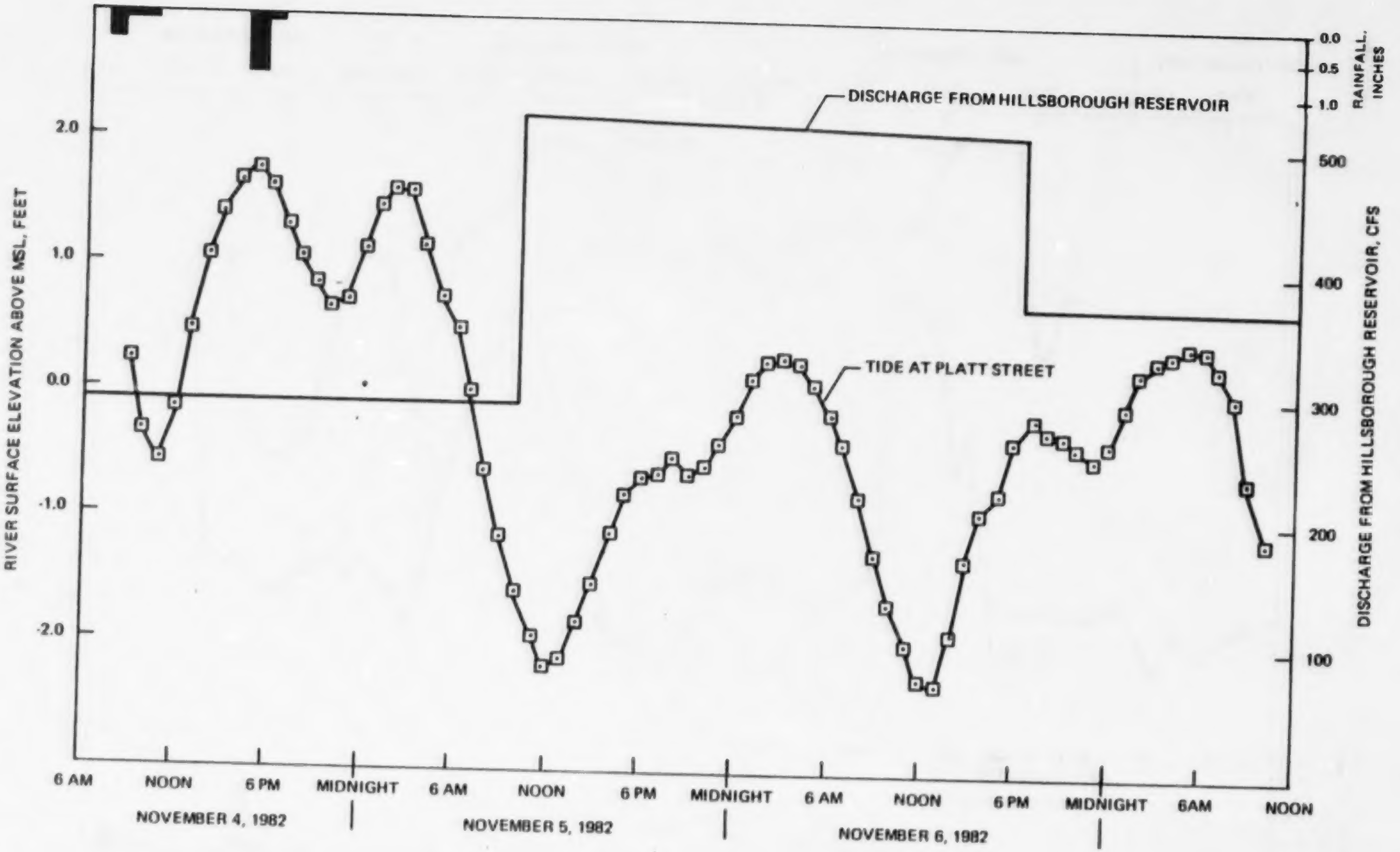

FIG. 3-8 TIDAL HEIGHT AT PLATT STREET AND HILLSBOROUGH RESERVOIR DISCHARGE
NOVEMBER 4-7, 1982

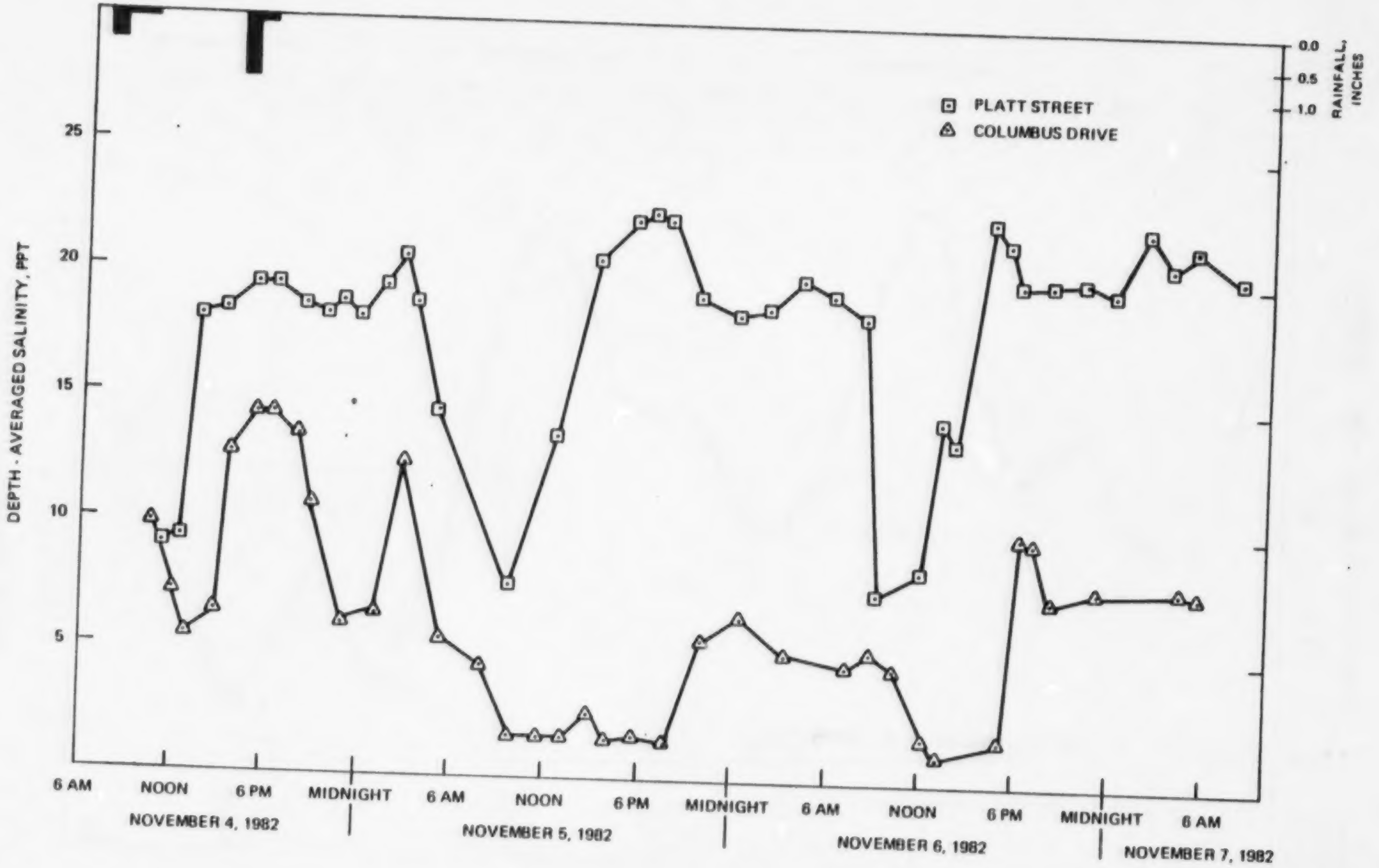

FIG. 3-9 DEPTH - AVERAGED SALINITY CONCENTRATIONS - NOVEMBER 4 - 7, 1982

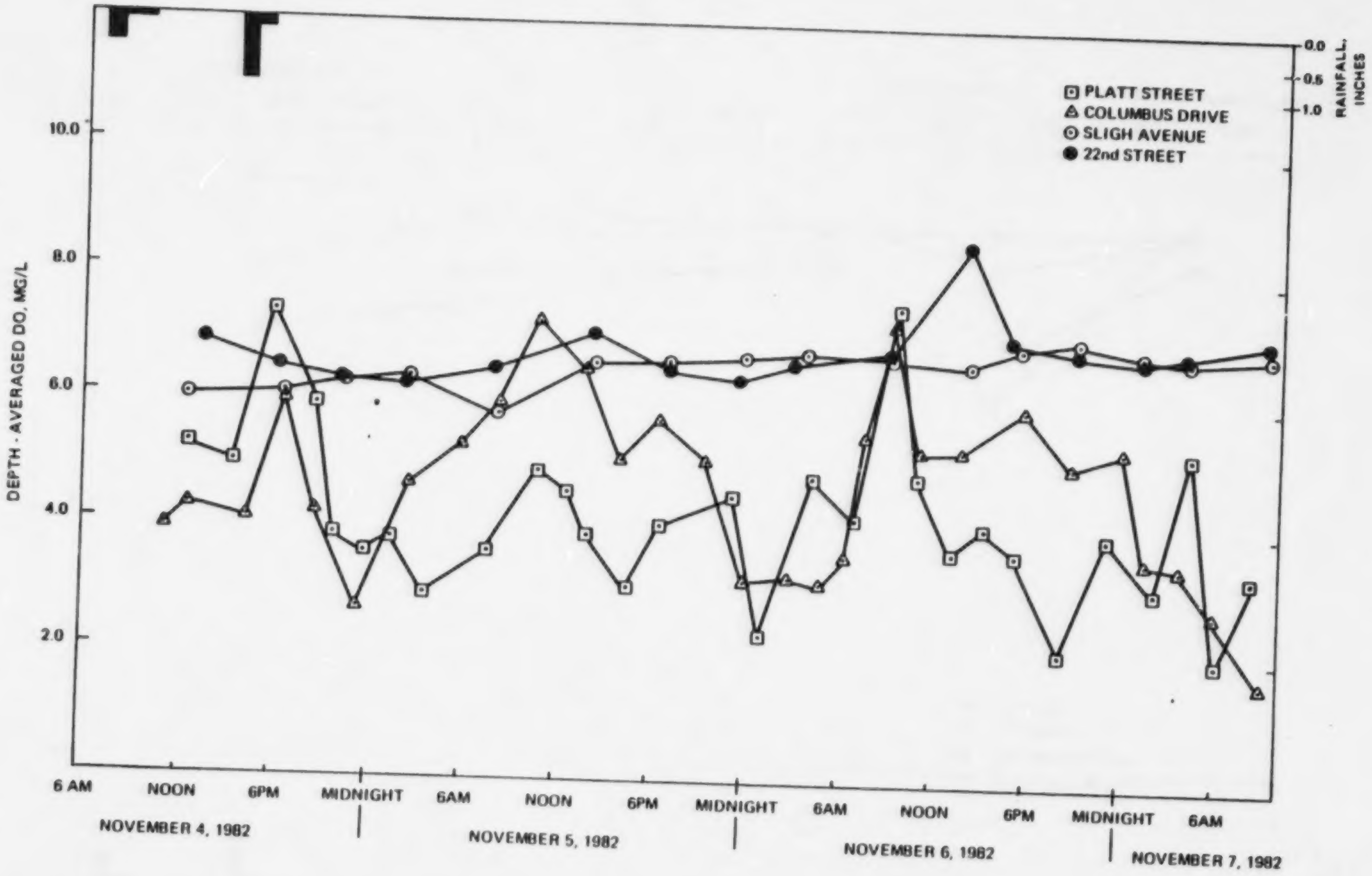

FIG. 3-10 DEPTH-AVERAGED DISSOLVED OXYGEN CONCENTRATIONS - NOVEMBER 4-7, 1982

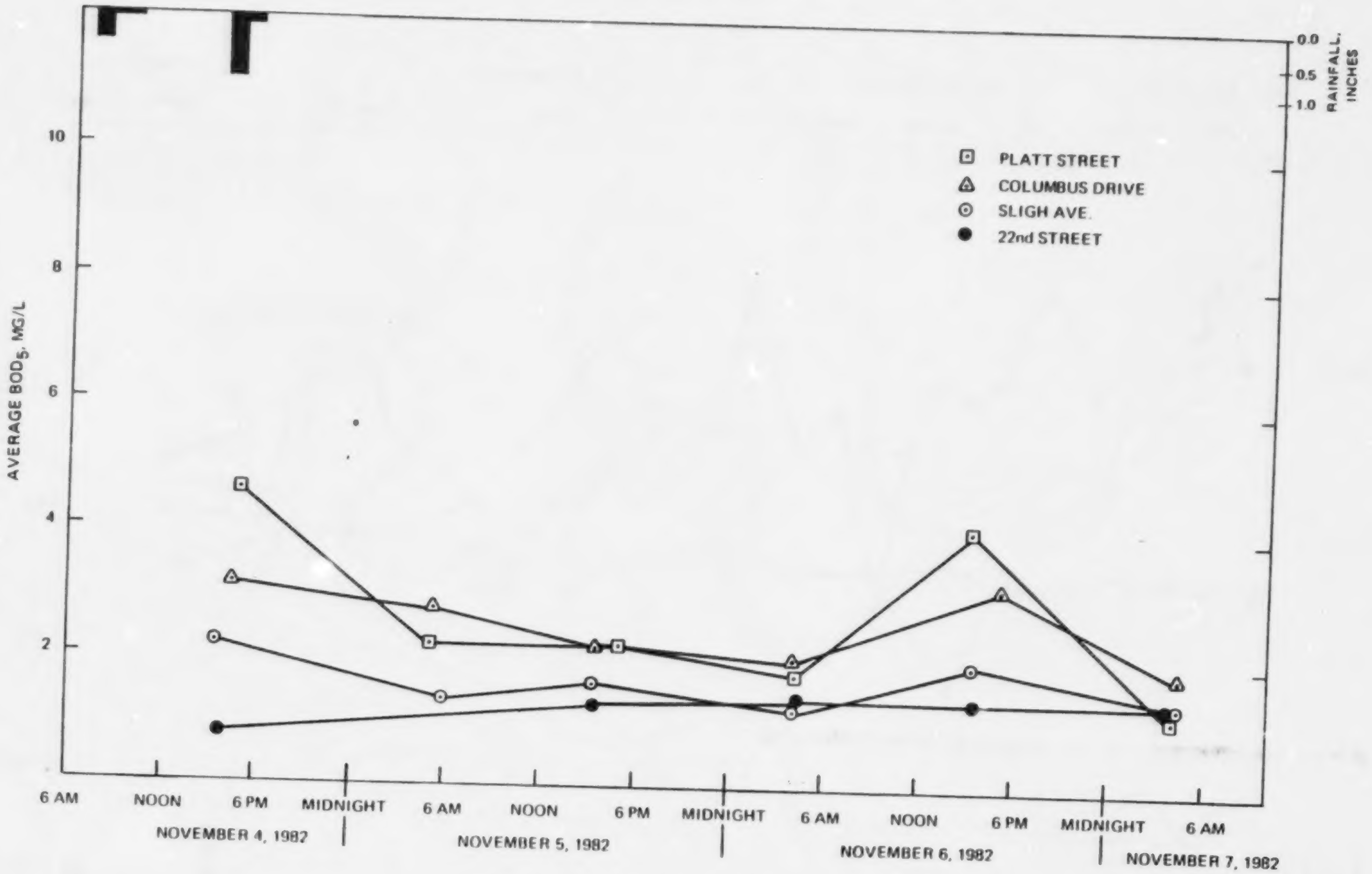

FIG. 3-11 AVERAGE BOD$_5$ CONCENTRATIONS - NOVEMBER 4-7, 1982

DO concentrations were near saturation levels at Sligh Avenue and 22nd Street and varied from 2 to 6 mg/l at the Columbus Drive and Platt Street stations. The DO concentrations at the two latter stations appear to vary with the tide, being lowest at high tide, and highest at low tide. BOD_5 concentrations were relatively low in the upstream reaches and did not increase despite the runoff to the River that resulted from the rainfall event.

Figure 3-12 presents the time-varying average total suspended solids (TSS) concentrations at all four stations. The effect of the storm on the River is not obvious from these data and the increases in TSS concentrations appear to occur randomly. Overall the TSS levels in the River are low. The concentrations at Columbus Drive and Platt Street are higher than those at upstream stations.

Average total and fecal coliform bacteria counts are presented in Figures 3-13 and 3-14, respectively. Total coliform counts are highest at 22nd Street and Sligh Avenue and appear to be a direct result of stormwater runoff. However the coliform increase again two days later at both stations though no rain event occurs. Columbus Drive and Platt Street total coliform counts vary from 30,000 to 90,000 MPN/100 ml throughout the entire survey. It appears that they are not flushed out by upstream inflows. Possible sewer leaks at Perry Crossing and in Seddon Channel may have been the source of these coliforms during this survey. In Figure 3-14, fecal coliform concentrations are

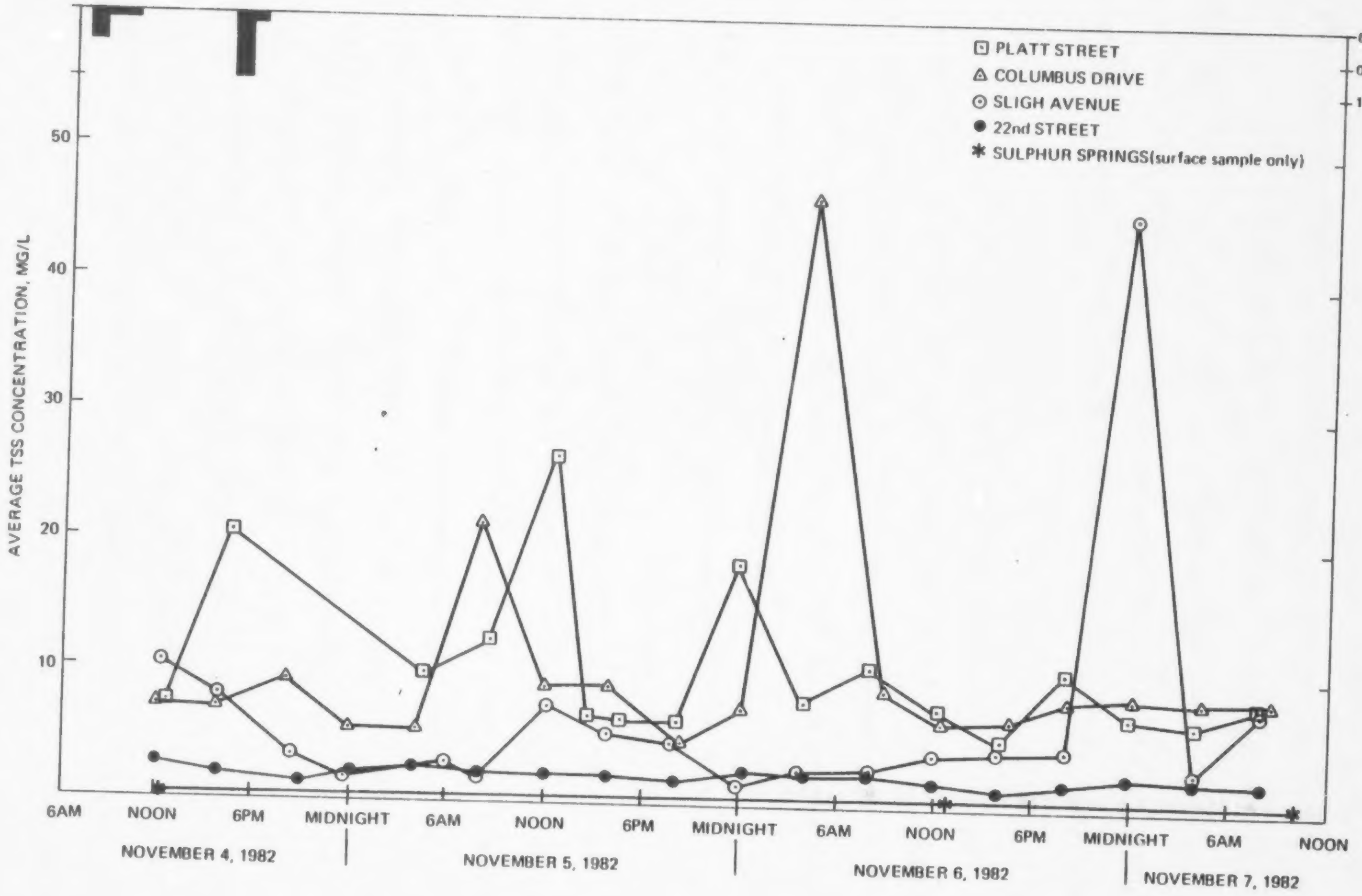

FIG. 3-12 AVERAGE TSS CONCENTRATIONS - NOVEMBER 4-7, 1982

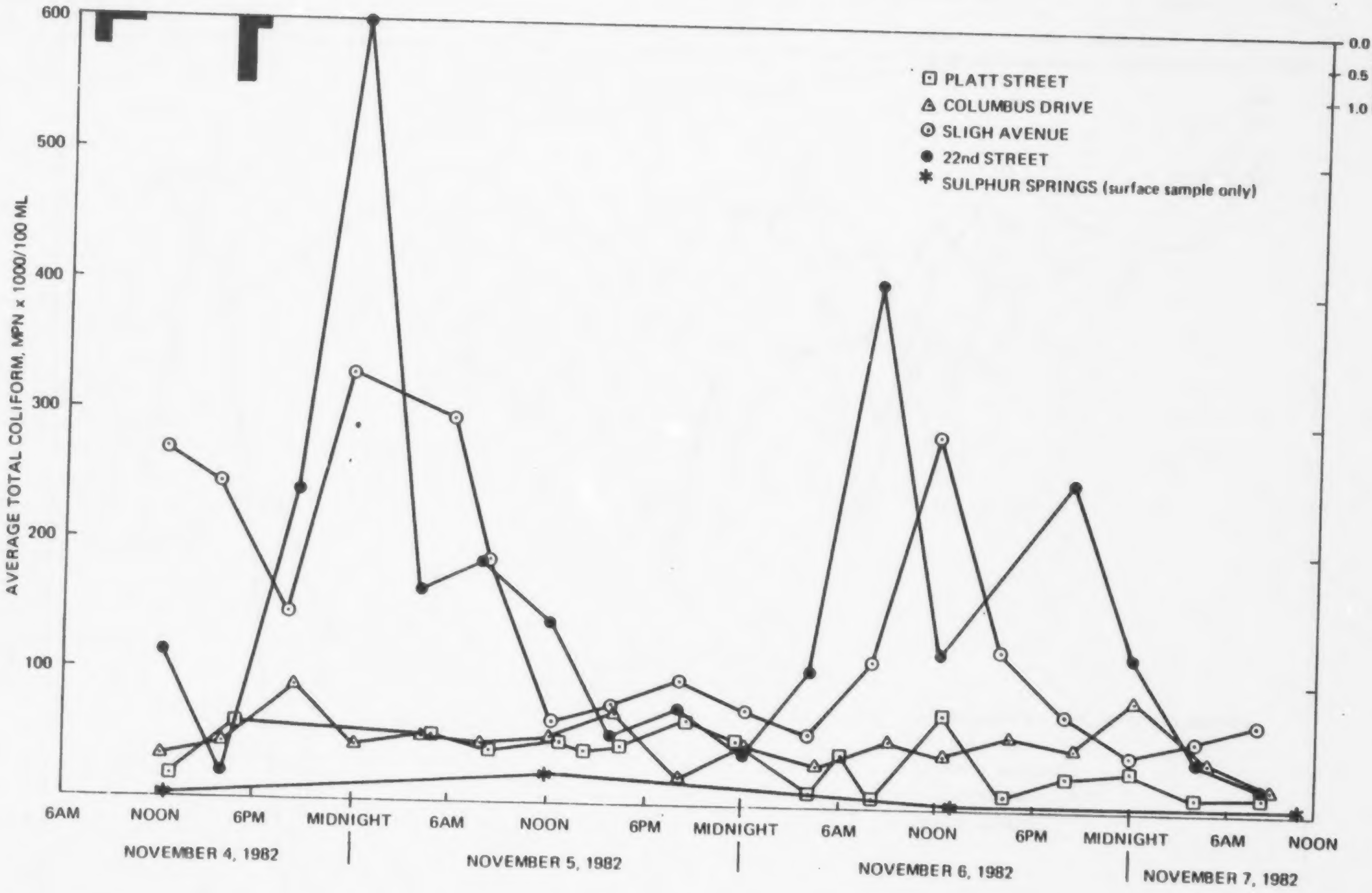

FIG. 3-13 AVERAGE TOTAL COLIFORM CONCENTRATIONS - NOVEMBER 4-7, 1982

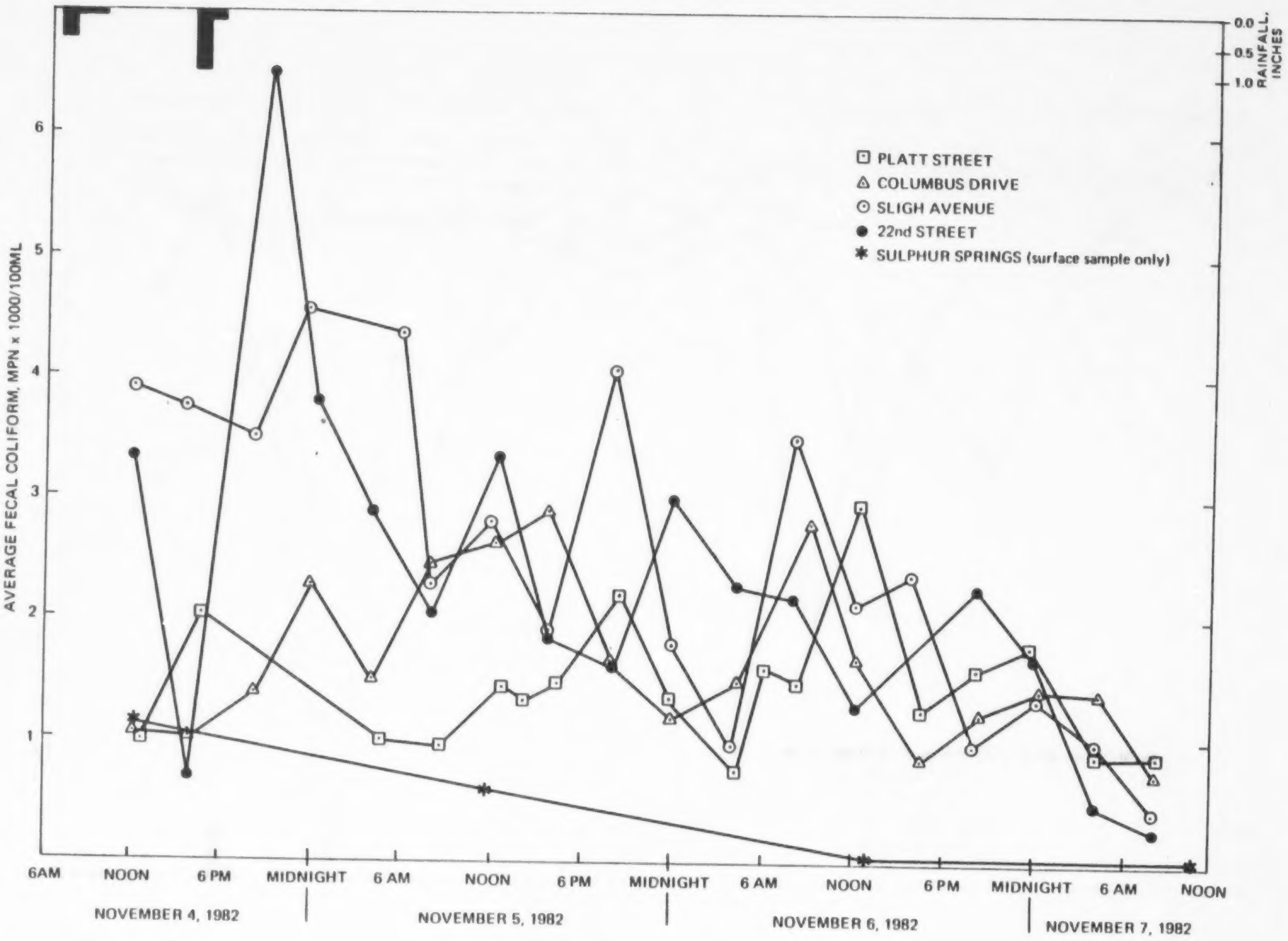

FIG. 3-14 AVERAGE FECAL COLIFORM CONCENTRATIONS - NOVEMBER 4-7, 1982

again highest near Sligh Avenue and 22nd Street. An overall decrease of fecal coliform bacteria is observed at all stations during the survey. On November 7, 1982, three days after the storm event, the fecal coliform fall below 1,000 MPN/100 ml at all stations, indicating that high bacteria counts can be present in the River for about 3 days after a rain storm. It should be noted that the storm-induced increase in total and fecal coliform bacteria is generally within one order of magnitude.

Table 3-5 indicates the range of concentrations for various other parameters. Nutrient concentrations measured during the survey in general are lower than those shown during the April survey. They tend to increase downstream, most likely due to the higher freshwater release from the Reservoir which flushes out the Hillsborough Bay water. The Bay appears to be the major source of nutrients.

Lead and copper concentrations are generally higher than those in Table 3-4 (the dry survey in April, 1982). This may be indicative of the input of stormwater runoff containing lead and copper. It could also be the higher freshwater flow and resulting input from the upstream drainage basin. Zinc concentrations, however, are lower than during the April, 1982 survey despite the storm.

TABLE 3-5. CONCENTRATION RANGES FOR PARAMETERS MEASURED IN THE NOVEMBER 4-7, 1982 SURVEY

Parameter	Range of measured concentrations	Comment
COD (mg/l)	6.6 - 59.7	Low at Sulphur Springs; other stations all similar.
Organic N (mg/l)	0.84 - 1.13	Slight increase downstream.
NO_2-N (mg/l)	0.01 - 0.02	Same at all stations.
NO_3-N (mg/l)	0.11 - 0.73	Highest at Columbus Drive; increase with time at Sligh Avenue and Columbus Drive.
NH_3-N (mg/l)	0.06 - 0.14	Higher concentrations downstream.
PO_4-P (mg/l)	0.23 - 0.48	Higher concentrations downstream.
P (mg/l)	0.26 - 0.52	Higher concentrations downstream.
VSS (mg/l)	1.2 - 7.5	Highest at Platt; other stations are lower and have similar ranges.
Copper (ug/l)	13 - 57	High at 22nd Street and Columbus Drive after storm, then decreases. At Sligh and Platt intial concentrations low but increase slightly over time.
Lead (ug/l)	8 - 22	High after storm but generally decrease at all stations.
Dissolved Lead (ug/l)	4 - 20	In general, high after storm then decrease.
Zinc (ug/l)	3.6 - 22	High after storm then decrease at all stations.

Storm Event - Low Freshwater Discharge. Another 72-hour survey was conducted before, during and after a rainstorm on February 1-4, 1983. Approximately 20 hours into the survey about 3.6 inches of rain fell over a 4-hour period. This survey was to be performed with no freshwater release from the Reservoir. However, a release of freshwater (about 355 cfs) occurred for 2 hours after the rainstorm. The tidal variation and rainfall are shown in Figure 3-15. The impact of the large rainfall volume on tidal height can be seen at about 7:00 AM.

The depth-averaged values of salinity at all four stations are shown in Figure 3-16. It can be seen that the saline wedge was present at 22nd Street at the start of the survey. After the rainfall and Reservoir release, there is an immediate drop in salinity at all stations. The salinity is almost completely flushed from 22nd Street. At Sligh Avenue and Columbus Drive, the salinity slowly begins to recover; however it appears that several more days would be required to get back to the initial condition.

The depth-averaged DO concentrations in the river are presented in Figure 3-17. The DO levels at Platt Street and Columbus Drive are about 6 mg/l and do not seem to be greatly affected by the stormwater runoff entering the River after the storm event. The lowest DO concentrations were at Sligh Avenue (about 5 mg/l) at the start of this survey. There is a definite downward trend after the storm event. DO levels at 22nd Street are several mg/l above the DO saturation level at the start of

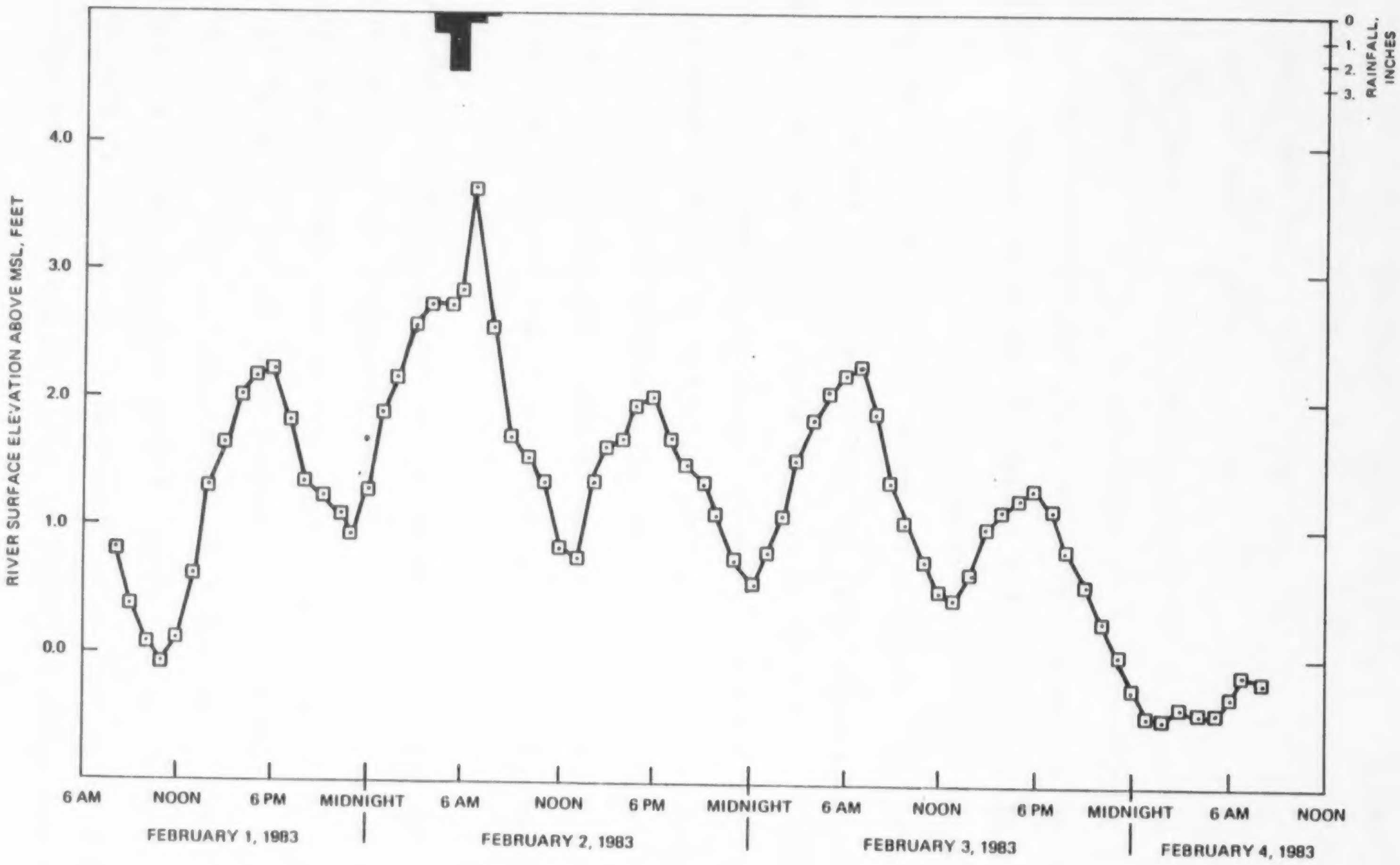

FIG. 3-15 TIDAL HEIGHT AT PLATT STREET - FEBRUARY 1-4, 1983

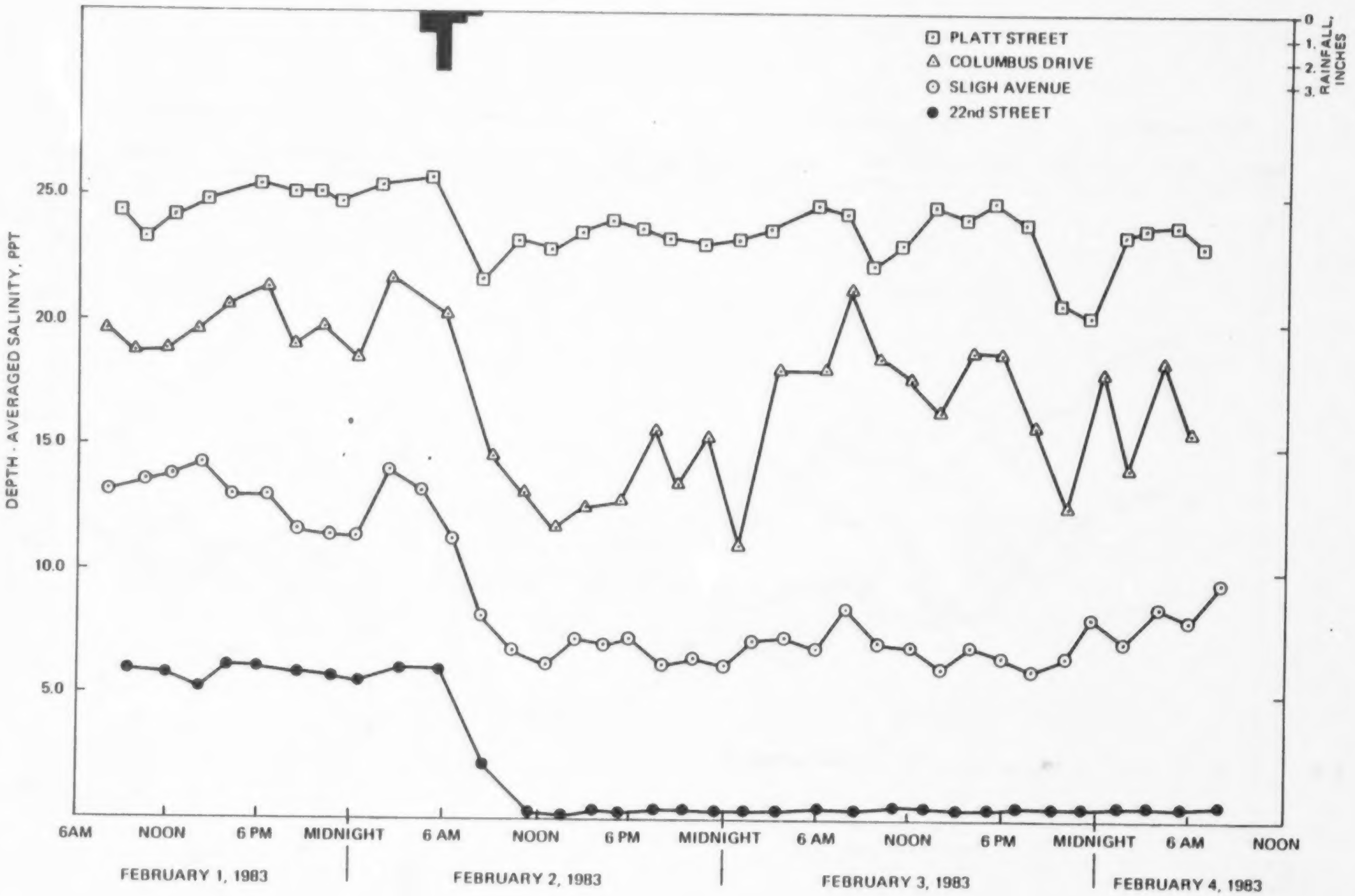

FIG. 3-16 DEPTH - AVERAGED SALINITY CONCENTRATIONS - FEBRUARY 1-4, 1983

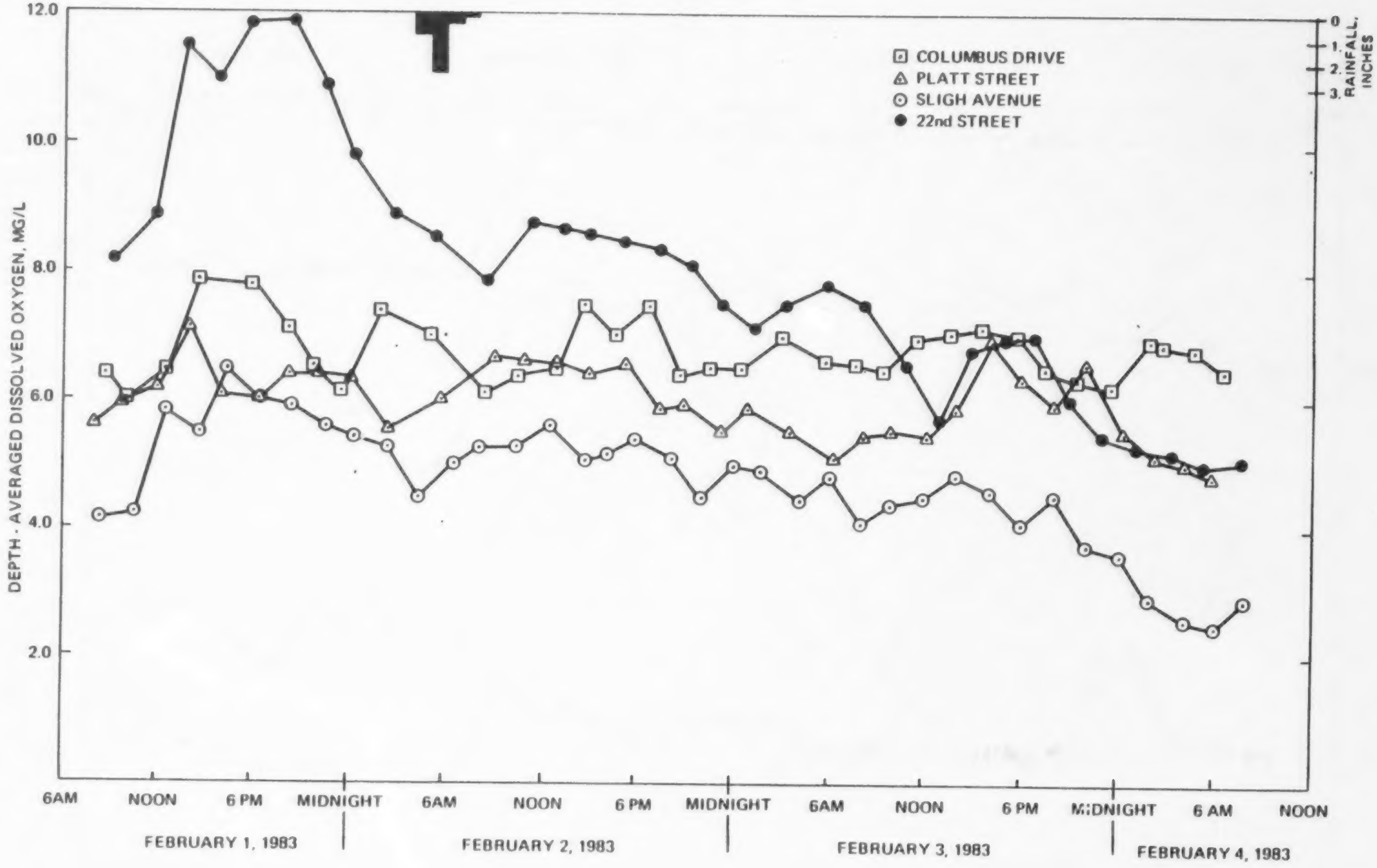

FIG. 3-17 DEPTH - AVERAGED DISSOLVED OXYGEN CONCENTRATIONS - FEBRUARY 1-4, 1983

the survey indicating algal activity. The DO levels at this station also indicate a definite downward trend in response to the event.

Average BOD_5 concentrations in the river are also influenced by the large storm event shown in Figure 3-18. It appears that a slug of BOD enters the River at 22nd Street immediately after the storm and then moves downstream to Sligh Avenue and then to Columbus Drive. In Figure 3-19, the total suspended solids concentrations all increase in unison after the storm and then drop to their pre-storm levels within a day. The unusually high TSS value measured at 22nd Street on February 3, 1983 appears to be an outlier value.

Total coliform concentrations, presented in Figure 3-20, are very low at all stations but 22nd Street before the storm begins. Coliform counts are not as high as those in the November survey. The highest total coliform counts were 300,000 to 600,000 MPN/100 ml in November while those from the February storm are all less than 80,000 MPN/100 ml. This may be due to the larger volume of stormwater runoff in the February storm which would dilute the pollutant concentrations. Coliform levels slowly decrease during the survey but have not reached pre-storm levels by the end of the survey. The lack of freshwater discharge (and thus flushing) from the Reservoir may play a role in the slow decline of coliform levels.

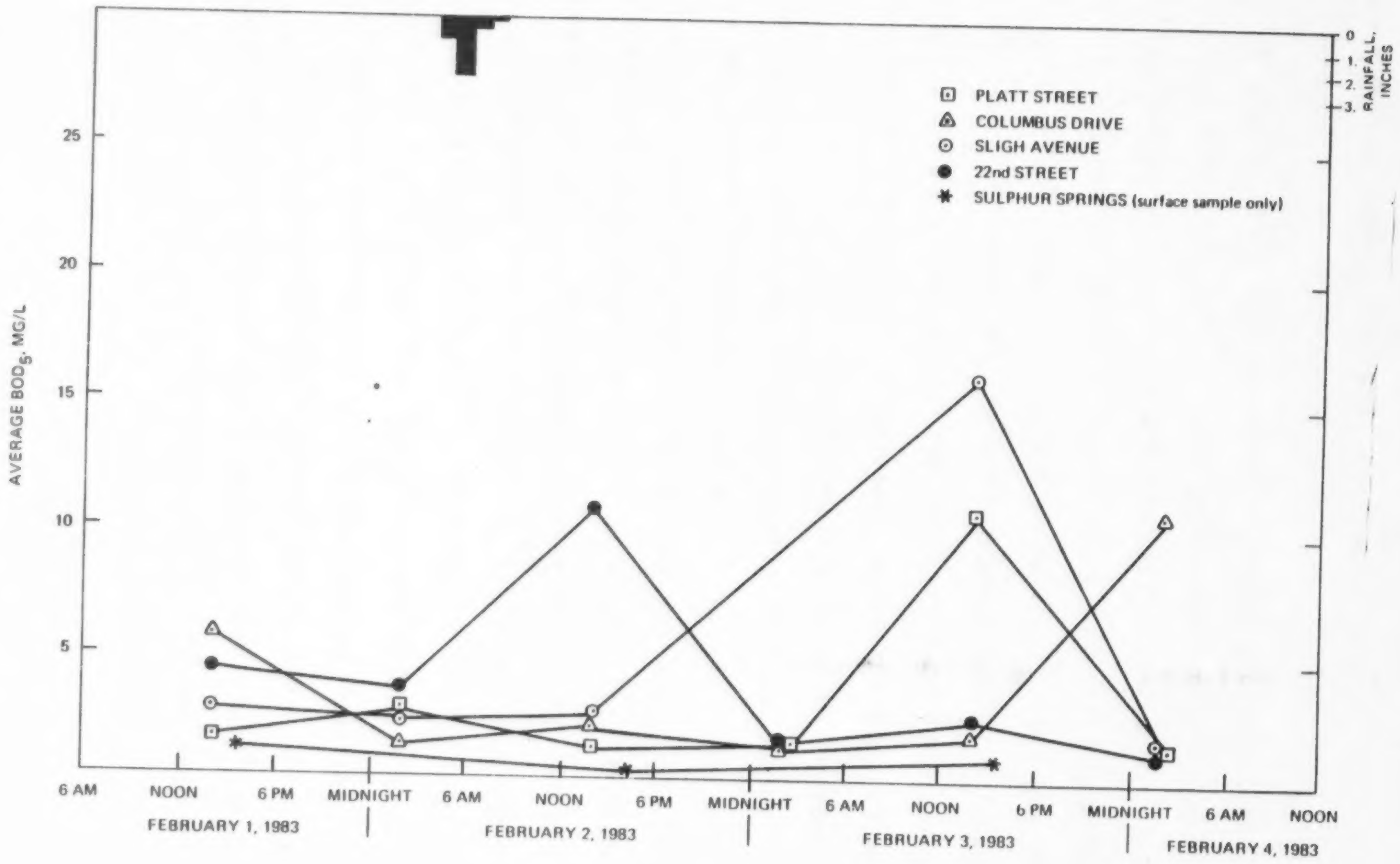

FIG. 3-18 AVERAGE BOD$_5$ CONCENTRATIONS - FEBRUARY 1-4, 1983

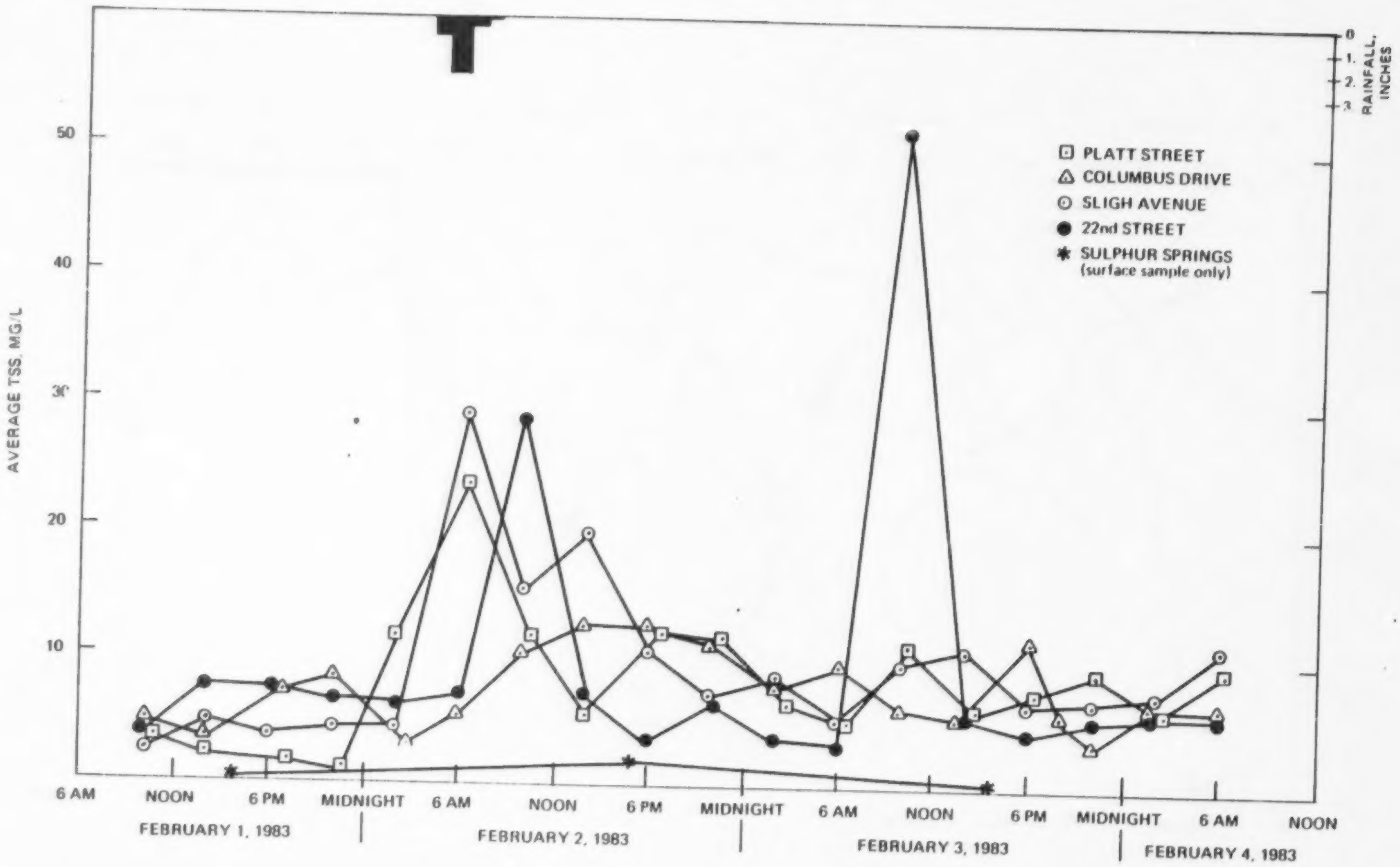

FIG. 3-19 AVERAGE TSS CONCENTRATIONS - FEBRUARY 1-4, 1983

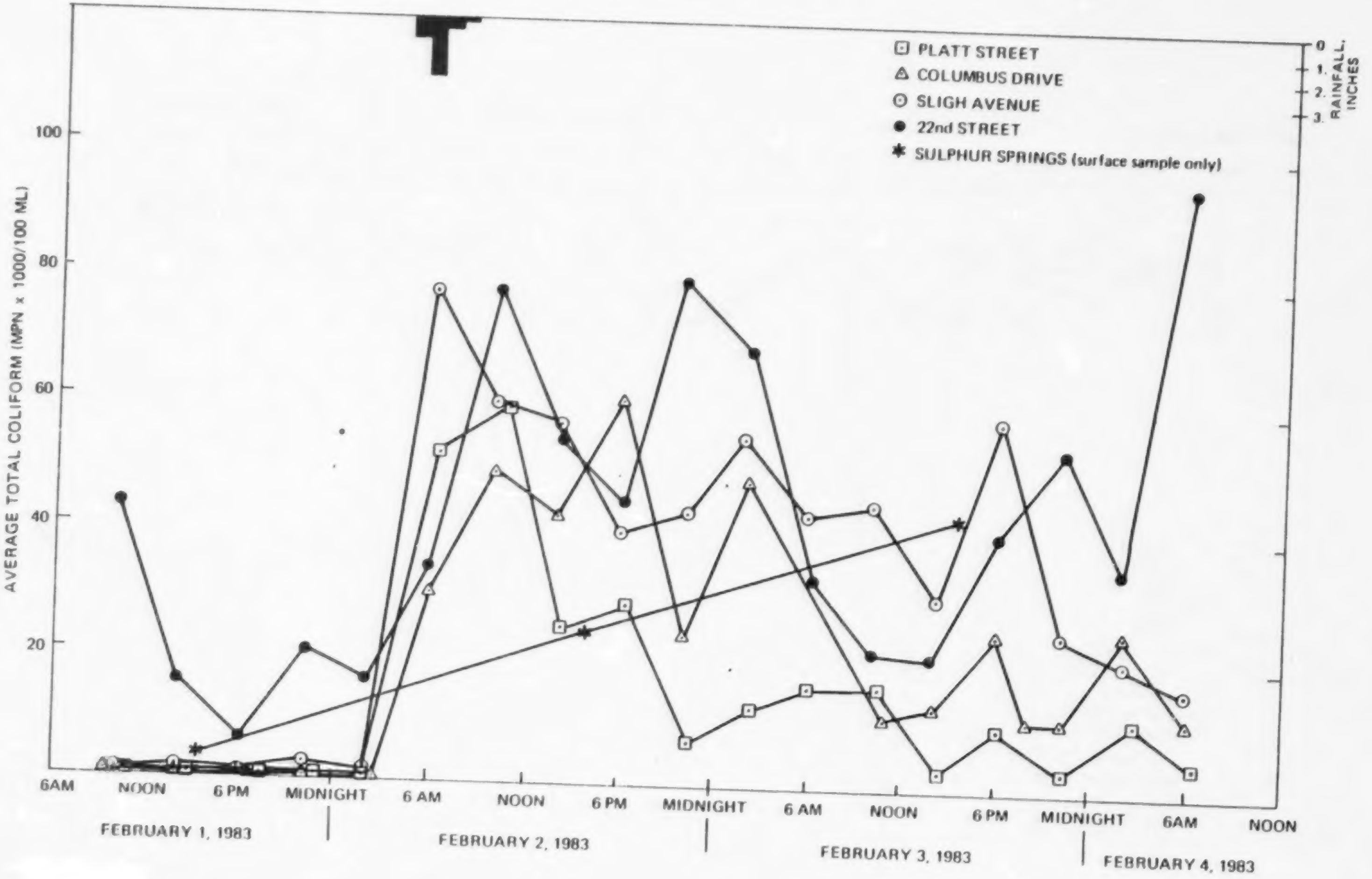

FIG. 3-20 AVERAGE TOTAL COLIFORM CONCENTRATIONS - FEBRUARY 1-4, 1983

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The fecal coliform concentrations are presented in Figure 3-21. Three of the stations show fecal coliform levels in the same range (1,000 to 6,000 MPN/100 ml) as observed in the November survey. Sligh Avenue concentrations of fecal coliform are at least four times higher than other stations. It is interesting to note that these high counts are not observed at downstream stations later on in the survey. The impact of this storm event on both total and fecal coliform bacteria in the River is significant and clearly identifiable.

Table 3-6 indicates the range of concentrations for other parameters measured during this survey. Nutrient levels are generally comparable to those in previous surveys. The chlorophyll a measurements were highest at 22nd Street thus confirming the presence of algae in that vicinity. Chlorophyll a concentrations were signficantly reduced on the day of the storm event, and then started to increase on the day after.

Dry Weather - No Freshwater Discharge. The final synoptic survey was performed over a 24-hour period on May 16-17, 1983. This was a dry weather survey with no Reservoir discharge. Although there was no freshwater discharge for at least 14 days prior to the survey, flows during April and May, 1983 had been extremely high. The tidal variation during the survey is shown in Figure 3-22. Depth-averaged salinity concentrations at all four stations are shown in Figure 3-23. Some salinity is present at 22nd Street but is not as high as at the start of the February survey (Figure 3-16). The salinity variation with tide is evident.

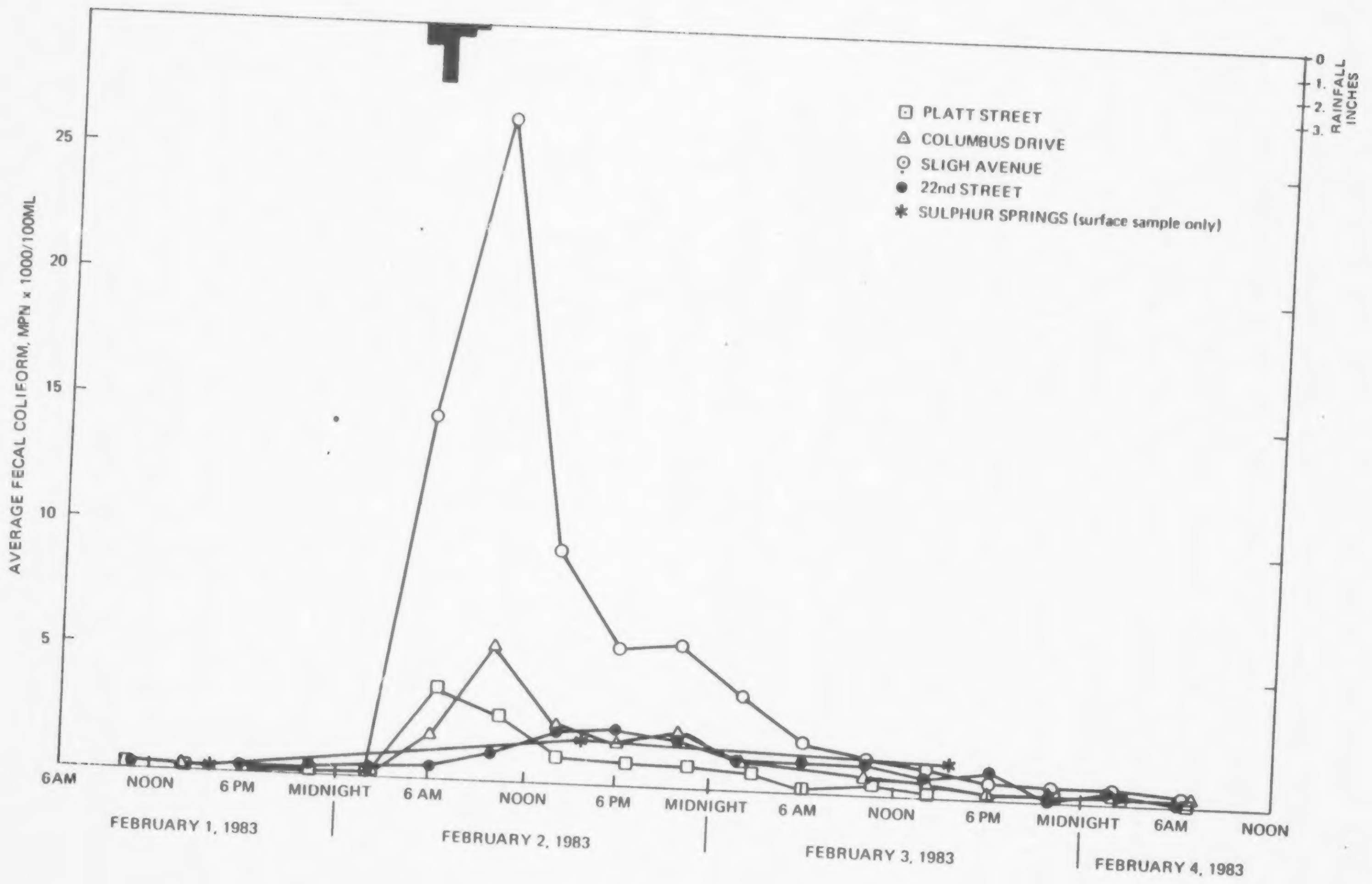

FIG. 3-21 AVERAGE FECAL COLIFORM CONCENTRATIONS - FEBRUARY 1-4, 1983

TABLE 3-6. CONCENTRATION RANGES FOR PARAMETERS MEASURED IN THE FEBRUARY 1-4, 1983 SURVEY

Parameter	Range of measured concentrations	Comment
COD (mg/l)	7 - 41	Reduced by storm event. Higher concentrations downstream.
Organic N (mg/l)	0.09 - 1.88	Reduced by storm event. Higher concentrations downstream.
NO_2-N (mg/l)	0.01 - 0.02	No pattern.
NO_3-N (mg/l)	0.08 - 0.90	Higher upstream; concentrations decrease overall.
NH_3-N (mg/l)	0.02 - 0.25	Increases with time at upstream stations.
PO_4-P (mg/l)	0.08 - 0.41	Higher concentrations downstream.
P (mg/l)	0.15 - 0.43	Higher concentrations downstream.
VSS (mg/l)	<.4 - 6.8	No pattern.
Chlorophyll a (mg/m^3)	0.5 - 47.1	Higher upstream and decrease after storm event.

Depth-averaged dissolved oxygen concentrations are shown in Figure 3-24. Sligh Avenue exhibits the lowest DO levels which indicates that the saline wedge is probably in this vicinity. The DO concentrations at 22nd Street (where the salinity has not intruded) respond to a diurnal cycle of algal photosynthesis and

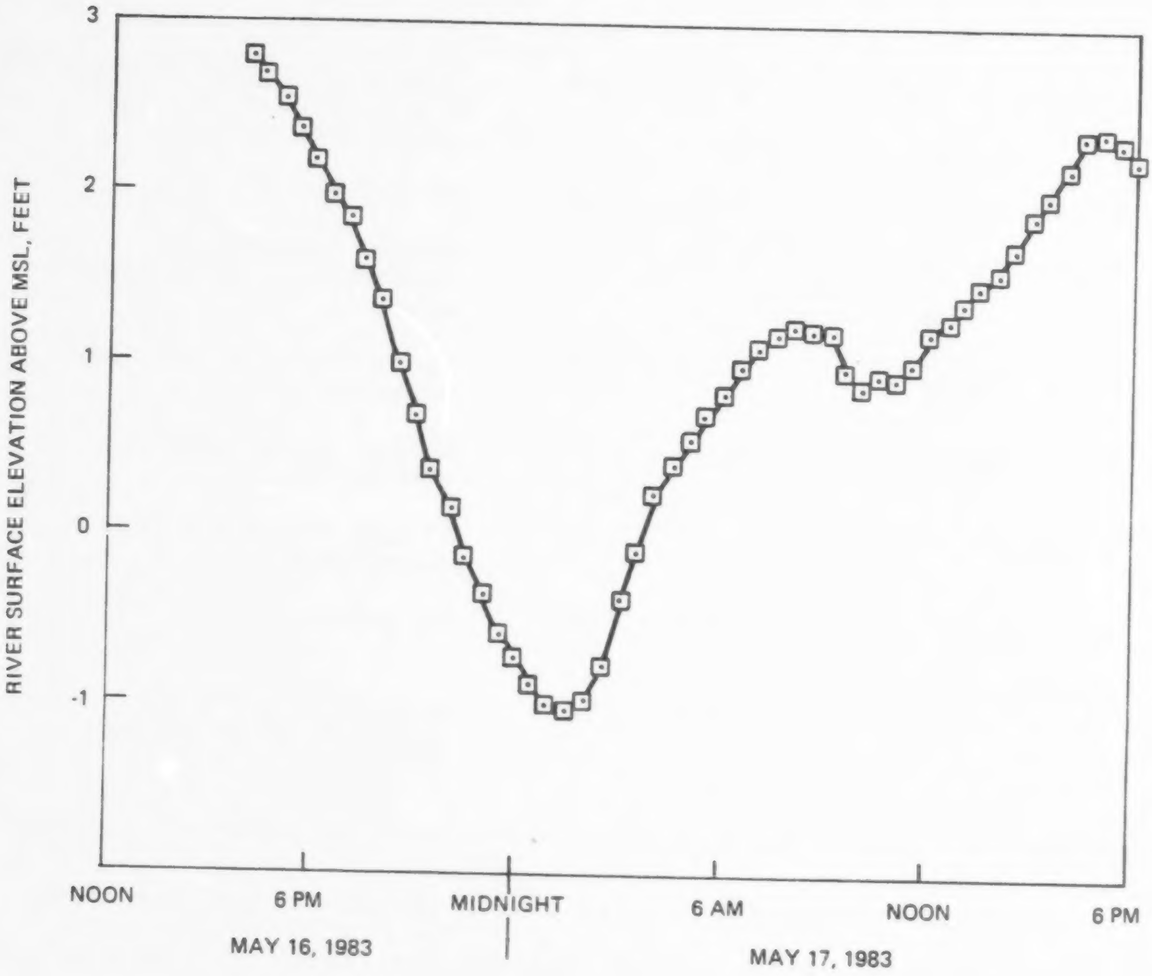

FIG. 3-22 TIDAL HEIGHT AT PLATT STREET - MAY 16-17, 1983

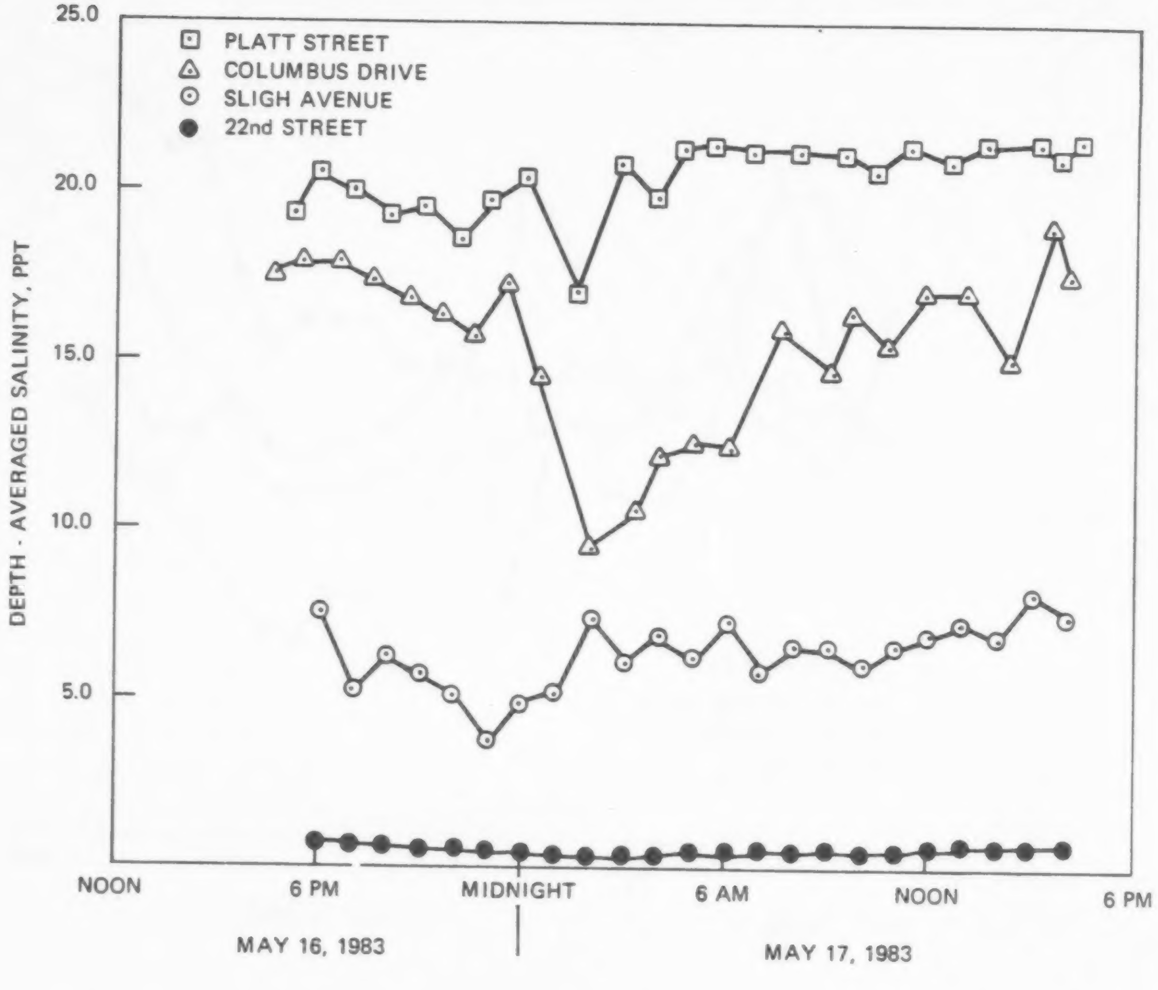

FIG. 3-23 DEPTH - AVERAGED SALINITY CONCENTRATIONS
MAY 16-17, 1983

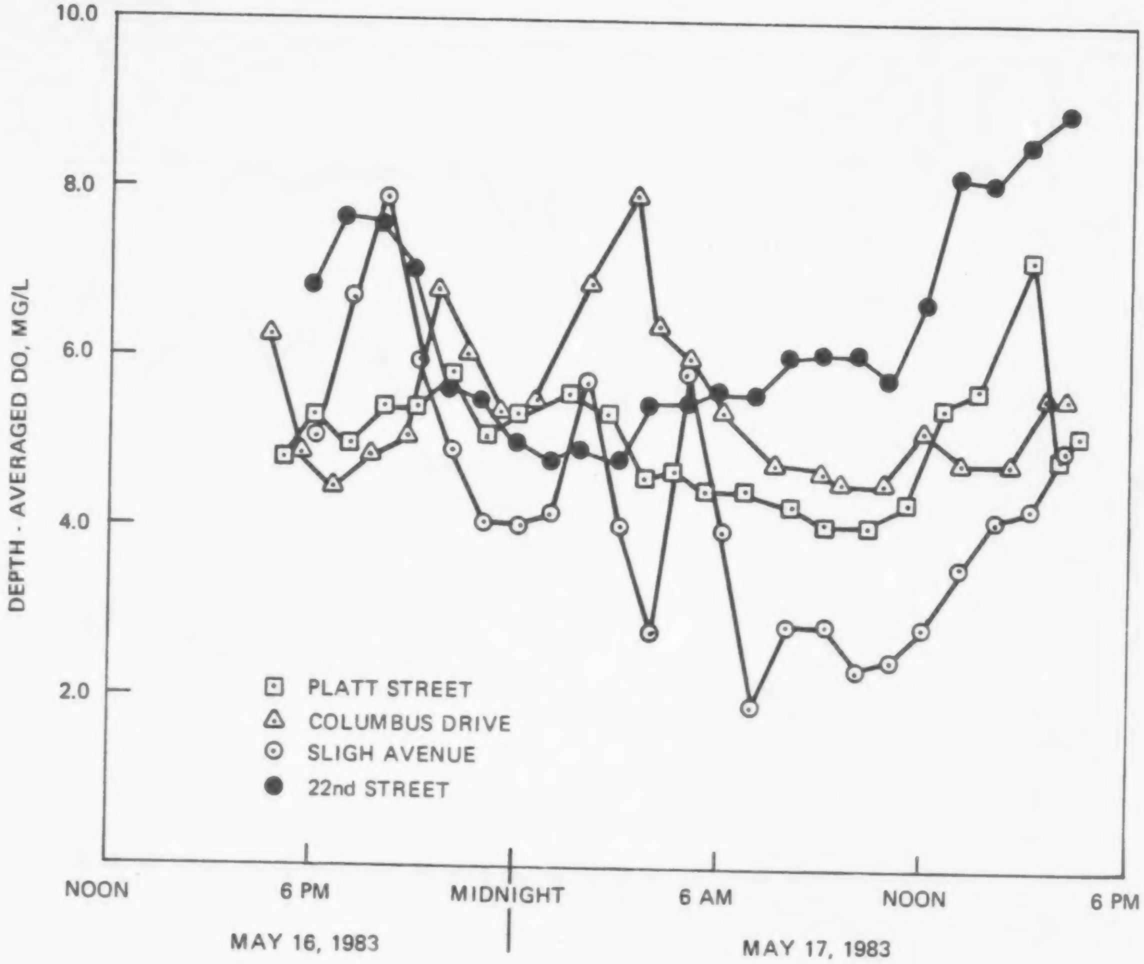

FIG. 3-24 DEPTH - AVERAGED DISSOLVED OXYGEN CONCENTRATIONS
MAY 16-17, 1983

respiration. Downstream at Sligh Avenue and Columbus Drive, the DO responds to the tidal variations as well. The interaction of these effects damps significant increases in DO such as that which occurs in the late afternoon at 22nd Street.

Summary

The five synoptic surveys have provided data that reflect a variety of meteorologic and hydrologic conditions in the lower Hillsborough River. Their discussion in this Chapter has identified a number of processes and interactions, some of which were raised in the Phase I Report of the NURP Study (1) and in Chapter 2 of this report. These include:

1. The dissolved oxygen concentrations in the lower Hillsborough River are directly related to the freshwater releases from the Hillsborough Reservoir which dictate the extent of saline penetration in the River. It appears that the lowest dissolved oxygen concentrations are found near the upstream penetration of the saline wedge. In the September 1981 survey the high fresh water flow of 1000 cfs moved the wedge close to Platt Street where the lowest DO concentrations were measured (Figure 3-3). In the April 1982 survey the saline wedge was near Sligh Avenue (120 cfs of freshwater discharge) as reflected in DO concentrations in Figure 3-6. The 300 to 500 cfs freshwater discharge in November 1982 brought the wedge near Columbus Drive. The accidental Reservoir

release during the February 1983 survey moved the wedge to Sligh Avenue (Figure 3-17). Finally in the May, 1983 survey the saline wedge was again near Sligh Avenue (Figure 3-24). Each of these locations had the lowest DO concentrations in the River during that day.

2. Levels of BOD in the River are usually 1 to 4 mg/l. BOD levels rise slightly after rainstorms, but their impact on DO levels is not as significant as the background River conditions which result in frequent DO standard violations.
3. If algal activity is present during periods of low freshwater discharge, stormwater runoff tends to flush out the algae and DO concentrations subsequently drop to levels below DO saturation.
4. Stormwater runoff is the primary source of total and fecal coliform in the lower Hillsborough River as seen in the November 1982 and February 1983 surveys. However, coliform concentrations that violated State criteria were also observed during the dry weather April, 1982 survey.
5. Stormwater runoff results in increased solids concentrations in the lower River.
6. Concentrations of copper and lead in the lower Hillsborough River appear to increase after storm events as seen in comparing concentrations for the April and November 1982 surveys.

7. Nutrient concentrations in the River are fairly constant. TKN and phosphorus concentrations are usually higher in the downstream reaches of the River indicating that the major source is from Hillsborough Bay.

REFERENCES

1. Metcalf & Eddy, Inc., Phase I - Receiving Water Study, City of Tampa, Tampa Nationwide Urban Runoff Program Study, December, 1981.

CHAPTER 4

MODEL CALIBRATION AND VERIFICATION

General

The primary objective of the Receiving Water Study is to understand the various factors that affect water quality conditions in the lower Hillsborough River and the extent to which they affect the River. A second goal of this study is to predict future water quality conditions based on the implementation of various stormwater management plans in the City of Tampa and other management alternatives for the River.

The continuous data collection program and the synoptic survey program discussed in Chapters 2 and 3, respectively, have provided insights regarding the estuarine behavior of the lower River and the effects of stormwater runoff on hydrodynamics and water quality. In order to predict the impacts of alternative river improvement schemes, a calibrated model capable of simulating hydrodynamics and water quality is required. In this Chapter, the modeling approach and calibration and verification of this model are presented.

Modeling Approach

The analysis of data presented in earlier Chapters reflects the importance of tidal variation, freshwater releases from the Hillsborough Reservoir, and the subsequent location of the saline wedge on the water quality in the lower Hillsborough River. In order to predict future River water quality, a modeling approach is required which accounts for the tidal hydrodynamics, and the interaction of fresh and salt water and their impact on salinity concentrations in the River. These factors form the basis for simulation of dilution and flushing of pollutants, and must be accounted for with the river model used.

For this study the one-dimensional WQON (Water Quality of Open Channel Networks) model developed at the Massachusetts Institute of Technology (1) was used. WQON is a numerical model which has the capability of predicting hydrodynamics and transient water quality in an estuary. The model respresents the estuary as a one-dimensional (cross-sectionally averaged) system. WQON has the capability of solving for several water quality constituents, including salinity, BOD, DO and coliform bacteria. The numerical solution procedures for WQON are based on the finite element method.

The WQON modeling approach involves three steps as follows:

1. Simulate hydrodynamics (tide and velocity variations).
2. Simulate salinity (and the effect of density variations on hydrodynamics).
3. Simulate water quality.

In the second step, where salinities are simulated, the hydrodynamic results are modified because of a coupling in the model between hydrodynamics and salinity. This coupling accounts for the effect of salinity (and thus density) variations on the cross-sectionally averaged velocities. Once these steps are completed, water quality parameters such as BOD and DO may be simulated.

The model calibration and verification procedures require synoptic data, i.e., hydrodynamic and water quality data at several points along the River through one or more tidal cycles. To run hydrodynamics a Bay boundary is selected at which tidal variations are specified over time. Any freshwater flows to the River are also specified. A model run is made for one or more tidal cycles and the resulting tidal variations and velocities at various locations on the River are compared with measured data. Adjustments are made to such factors as the Manning's n for the stream channels until the predicted hydrodynamics agree with measured data.

Calibration of water quality in the River is done in the same manner. Either time-varying concentrations or a Bay boundary condition can be specified at the downstream boundary. The Bay boundary condition solves for a constituent concentration based on the direction of tidal flow. On flood tide a prescribed concentration is input directly to the model. On ebb tide, the transport of mass across the Bay boundary is determined by the advective flow to the Bay and the concentration gradient of the constituent in the lower River. This is an important feature of the model because it eliminates the necessity of specifying concentrations on the outgoing tide, which, for future conditions is unknown. Initial concentrations are input along the entire River and the model is run for one or more tidal cycles.

Reaction rates, dispersion coefficients and the initial concentration estimates are adjusted until a good agreement is obtained between predicted results and measured data.

Verification of the model requires a different set of measured hydrodynamics and water quality data. For this run no adjustments of hydrodynamic or water quality factors are made. Rather, good agreement between the model predictions and measured data is expected as a confirmation of the model's predictive abilities.

Model Input Data

The key model inputs for the lower Hillsborough River analysis include physical system characteristics, tides, freshwater flows, water quality boundary conditions, and reaction rates.

Physical Stream Channel Characteristics. The City of Tampa obtained detailed data on 21 cross-sections along the lower Hillsborough River in September 1982. At each cross-section location, depth measurements were taken at 10 to 50-foot intervals. The cross-section data were input to the model at 800 to 10,000-foot intervals. The WQON model interpolates cross-sectional area based on known depth-area-wetted perimeter relationships. The cross-sections in the lower River were often highly irregular.

The bottom profile of the lower Hillsborough River was obtained by the City of Tampa in early 1982. A fathometer run was made from the Platt Street bridge upriver to the Tampa Dam.

The recorded water depths were used in conjunction with the cross-section data to establish river bottom slopes.

The length of the River from Tampa Dam to Platt Street was subdivided into mesh points about 500 to 1,100 feet apart. Computational mesh points are selected to be small enough to provide an accurate representation of the River, but large enough to avoid unnecessary computational expense. Manning's n values for the stream channels varied from 0.025 at the downstream reaches to 0.035 in the upper segments of the River based on literature values for natural open channels. These were adjusted during the calibration process.

Tidal Variation. The Platt Street Station (Figure 2-1) was selected as the downstream or Bay boundary. Measurements of tidal variations and water quality were obtained at this station during all synoptic surveys. These data served as the downstream boundary conditions for all model runs. Tidal variation was input to the model at 900 second intervals. The model time step is selected to provide stable computational results while avoiding unnecessary computational expense.

Freshwater Flow. The Tampa Dam was used as the upstream boundary for the lower River. For hydrodynamic model runs, varying freshwater discharges from the Hillsborough Reservoir as measured by the U.S.G.S. were specified at this boundary. For water quality runs this boundary served as a point of constant concentration for various constituents. The other freshwater flow included in all model runs was Sulphur Springs, a natural groundwater discharge located about 2 miles downstream of the Tampa Dam.

Dispersion Coefficients. To model salinity variation in the lower Hillsborough River, the longitudinal dispersion must be accounted for. The empirical formulas for calculation of dispersion have been presented by Thatcher et al (2) as:

$$E_t = 77UnR_h^{5/6}$$

$$E_s = K\frac{(ds)}{(dx)}$$

$$K = 0.002u_oL(E_d)^{-1/4}$$

where

E_t = freshwater zone (Taylor's) dispersion coefficient (ft^2/s)

E_s = saltwater zone dispersion coefficient (ft^2/s)

K = dispersion parameter (ft^2/s)

U = freshwater velocity (ft/s)

n = Manning's friction coefficient

Rh = hydraulic radius (ft)

$\frac{ds}{dx}$ = longitudinal salinity gradient

u_o = maximum velocity at ocean boundary (ft/s)

L = length of estuary (ft)

E_d = estuary number

The total dispersion at any point in the River is then calculated as:

$$D = K E_s + m E_t$$

where m = a multiplier

The parameters K, L and m are direct inputs to the WQON model and the total dispersion D is calculated internally by the model. In the zone of saltwater intrusion, dispersion is due mostly to the density-induced circulation and the total dispersion is dominated by the term KE_s. Upstream of the saltwater zone dispersion is mainly caused by shear effects and the Taylor Dispersion coefficient, E_t is normally the only component of the total dispersion. The multiplier for Taylor's coefficient, m, functions as a calibration parameter to account for such factors as channel bends and irregularities.

A gross mean tidal dispersion coefficient can be estimated based on the following relationship by Stommel (3):

$$D_t = Q\, S_A/(A_T\, dS_A/dx)$$

where

D_t = gross mean tidal dispersion coefficient (ft^2/s)

Q = average freshwater flow (cfs)

S_A = average salinity at a cross-section (ppt)

A_T = average tidal cross-sectional area (ft^2)

$\frac{dS_A}{dx}$ = average salinity gradient at a cross-section (ppt/ft)

By calculating an average total dispersion coefficient using this formulation, and obtaining values for E_s and E_t, the Taylor multiplier, m, can be estimated.

Reaction Rate Coefficients. First order reaction rates are assumed for all constituents solved by WQON and these rates must be input to the model. A BOD decay rate of 0.23/day, base e, was assumed as a typical decay rate for such systems (no long-term BOD tests were performed on River samples). Dissolved oxygen reaeration coefficients were calculated using the O'Connor-Dobbins formula which was most applicable to characteristic depths and velocities in the lower Hillsborough River.

Sediment Oxygen Demand. The bottom sediments in a river may significantly influence the quality of the overlying water. Utilization of organic matter by bacteria and benthic organisms will deplete the available oxygen in the water column. The amount of oxygen consumed is a function of a number of factors including the quantity of available organic food supply, the type and density of bacteria and benthic organisms and physical and chemical conditions in the River.

In order to determine the magnitude of this sediment oxygen demand (SOD) in the lower Hillsborough River, in-situ sampling was performed by the EPA (4,5). Two programs were conducted during low and high freshwater discharge. Four stations were sampled as shown in Figure 4-1.

Sediment oxygen demand rates were determined using clear and opaque plexiglass domes situated on the River bottom. Located within and mounted to the side of each dome was a pump with a diffuser used to circulate water within each chamber to cause a gradual mixing of entrapped water.

Monitoring equipment consisting of YSI Model S7 DO meters and probes with stirrers were placed into each dome. To account for primary production and respiration occurring within the

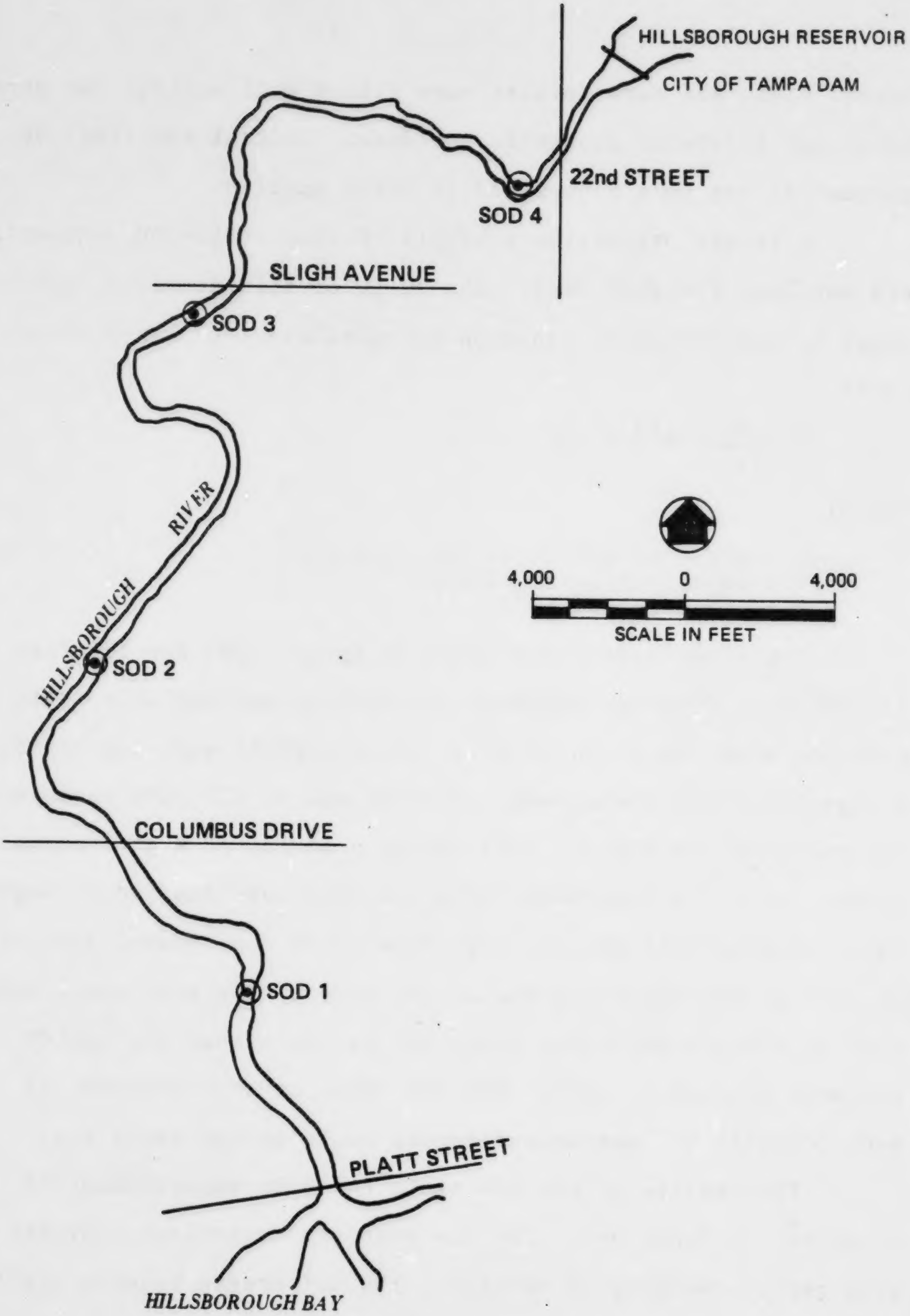
HILLSBOROUGH RESERVOIR
CITY OF TAMPA DAM
22nd STREET
SOD 4
SLIGH AVENUE
SOD 3
HILLSBOROUGH
RIVER
4,000
0
4,000
SCALE IN FEET
SOD 2
COLUMBUS DRIVE
SOD 1
PLATT STREET
HILLSBOROUGH BAY

FIG. 4-1 PLAN OF LOWER HILLSBOROUGH RIVER SHOWING SEDIMENT OXYGEN DEMAND SAMPLING STATIONS

domes, light and dark bottles were filled with ambient (at depth) water and incubated alongside the dome. Initial and final DO concentrations were determined in these bottles.

A linear regression analysis of time versus DO consumption was obtained for each dome. The slope of this curve, B, was input to the following equation to calculate the oxygen uptake rate:

$$B\,\frac{0.6V}{A} = gO_2/m^2/hr$$

where:

B = slope of the curve (mg O_2/L/min)
V = chamber volume (liters)
A = chamber area (m^2)

Experiments were conducted in April, 1981 for low flow conditions. Observed sediment composition was variable among all stations with the depth of thick black organic muds increasing with progression downstream. Another set of SOD rate experiments was conducted in August, 1982 during a period of high freshwater flows. Only stations SOD1, SOD2 and SOD3 were studied in August, 1982. During this period, high flow rates had scoured the layer of silt in the upper reaches of the River. The plexiglass dome used to measure SOD rates could not be positioned and sealed properly at Station SOD4. The SOD rates at this station, if it were possible to take measurements, would be extremely low.

The results of the SOD tests for both experiments are presented in Table 4-1. The low standard deviations indicate a good reproducability of results. The difference between light and dark tests was insignificant.

TABLE 4-1. AVERAGE SEDIMENT OXYGEN DEMAND RATES IN THE LOWER HILLSBOROUGH RIVER

Station	SOD Rates(1) (g O_2/m2/day)			
	April, 1981		August, 1982	
	Average	Standard Deviation	Average	Standard Deviation
SOD1	9.6	0.82	3.6	0.48
SOD2	4.3	0.28	1.1	0.46
SOD3	2.6	0.50	1.5	0.14
SOD4	4.1	0.62	(2)	

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1. Each rate is the average of 6 individual tests.
2. Test could not be conducted due to lack of presence of organic sediments.

It appears that SOD rates are strongly affected by the hydrologic conditions tested. The April tests were conducted after a 6 week period of negligible discharge from the Reservoir. Conversely the August tests occurred after 6 weeks of daily average flow ranging from 400 to 1,500 cfs. The stagnant conditions that are present in the River during periods of low freshwater discharge encourage the upstream transport of bottom organic material. This material imposes a higher demand on DO in the water column. High freshwater flows may scour silt deposits in various parts of the River as was noted in the August experiment at Station SOD4.

The SOD rates presented in Table 4-1 were input to the model as oxygen sinks along the River.

Model Calibration

To calibrate the model the measured data from the April 29-30, 1982 synoptic survey were used. The model inputs are summarized in Table 4-2. A varying river surface elevation corresponding to the measured tide at Platt Street during this survey was input at the downstream boundary. A varying discharge of 119 to 124 cfs was specified at the upstream boundary condition and an inflow of 48 cfs was specified at Sulphur Springs. Figures 4-2 through 4-5 present both measured and model-predicted river surface elevations and stream velocities at all four stations. The measured velocities were converted from mean point values to average cross-sectional values using rating curves developed by USGS from measurements performed in August and September, 1981. Positive velocities indicate downstream flow and negative velocities represent upstream flow.

Figures 4-3 and 4-4 show excellent agreement between measured and predicted river surface elevations. In Figure 4-5, however, a discrepancy is observed between measured and predicted river elevations. This is an example of the impact of shoal areas between 22nd Street and Sligh Avenue on the downstream water movement during ebb tide. This effect increases with increasing freshwater discharge from the Reservoir. As these shoal areas are localized it is not possible to incorporate them into the River model. Since the measured and predicted stream velocities match extremely well at all stations, it is not necessary to modify the stream channel characteristics in the upper reaches of the River.

TABLE 4-2. WQON MODEL INPUTS FOR CALIBRATION RUN

Parameter	Model Input
Tidal Variation at Bay Boundary	As measured at Platt Street on April 29-30, 1982
Freshwater Flow from Reservoir	119-124 cfs as measured by USGS
Sulphur Springs Discharge	48 cfs
Salinity at Bay Boundary	24.8 ppt
Salinity at Upstream Boundary	0.0 ppt
Dispersion Parameter, K	160 ft^2/sec
BOD at Bay Boundary	As measured at Platt Street on April 29-30, 1982
BOD at Upstream Boundary	As measured at 22nd Street on April 29-30, 1982
DO at Bay Boundary	As measured at Platt Street on April 29-30, 1982
DO at Upstream Boundary	As measured at 22nd Street on April 29-30, 1982
BOD decay rate	0.23/day
DO reaeration rate	0.17 - 0.32/day
Sediment Oxygen Demand	2.6 - 9.8 gO_2/m^2/day

To reproduce salinity conditions in the River, the extent of saline penetration upriver, the Reservoir freshwater release and the variation of salinity concentration along the River are taken into account. Based on conditions measured during the April 1982 survey, an estuary number, E_d, of 0.13 was obtained.

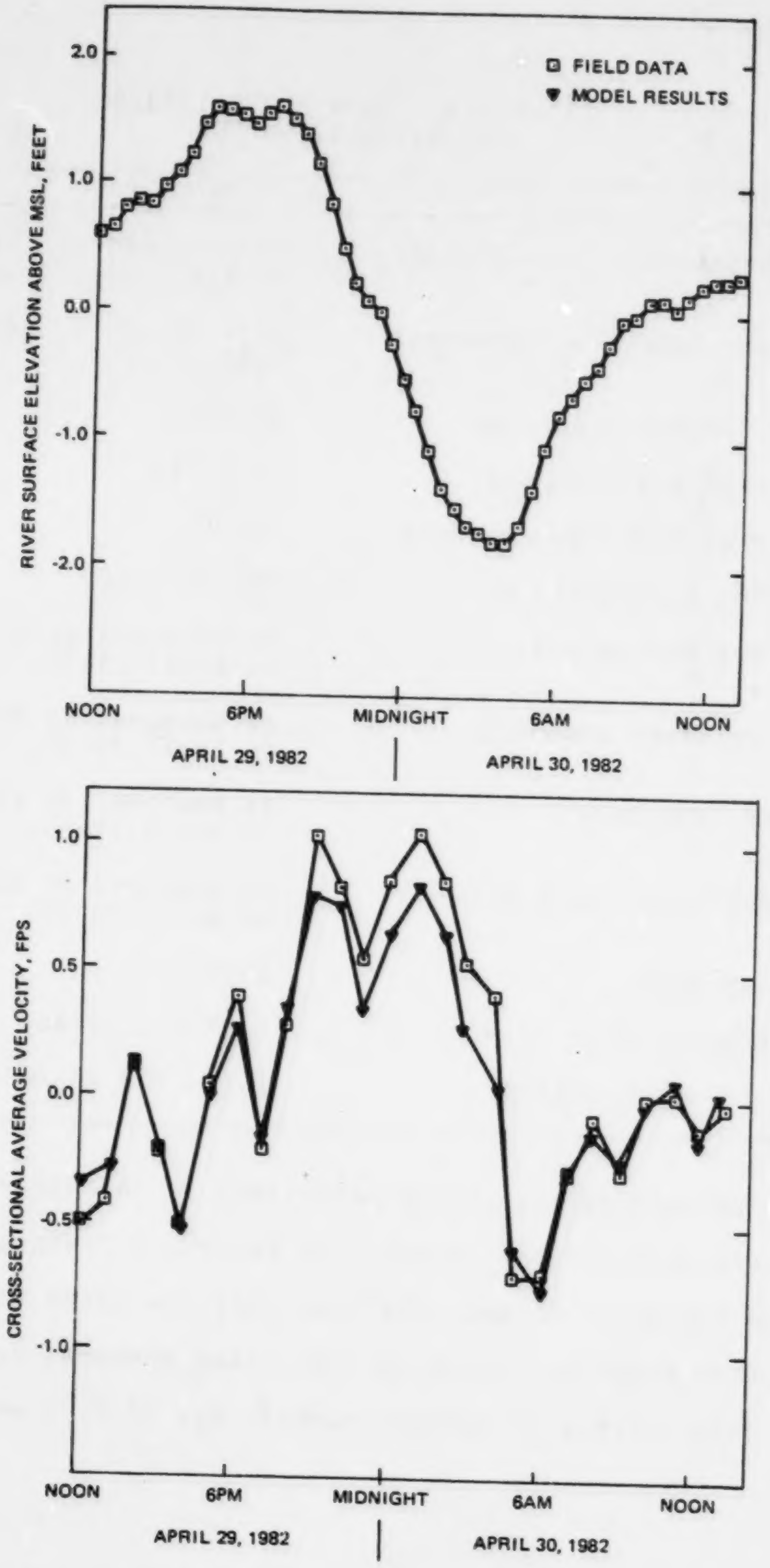


FIG. 4-2 HYDRODYNAMIC CALIBRATION RESULTS AT PLATT STREET

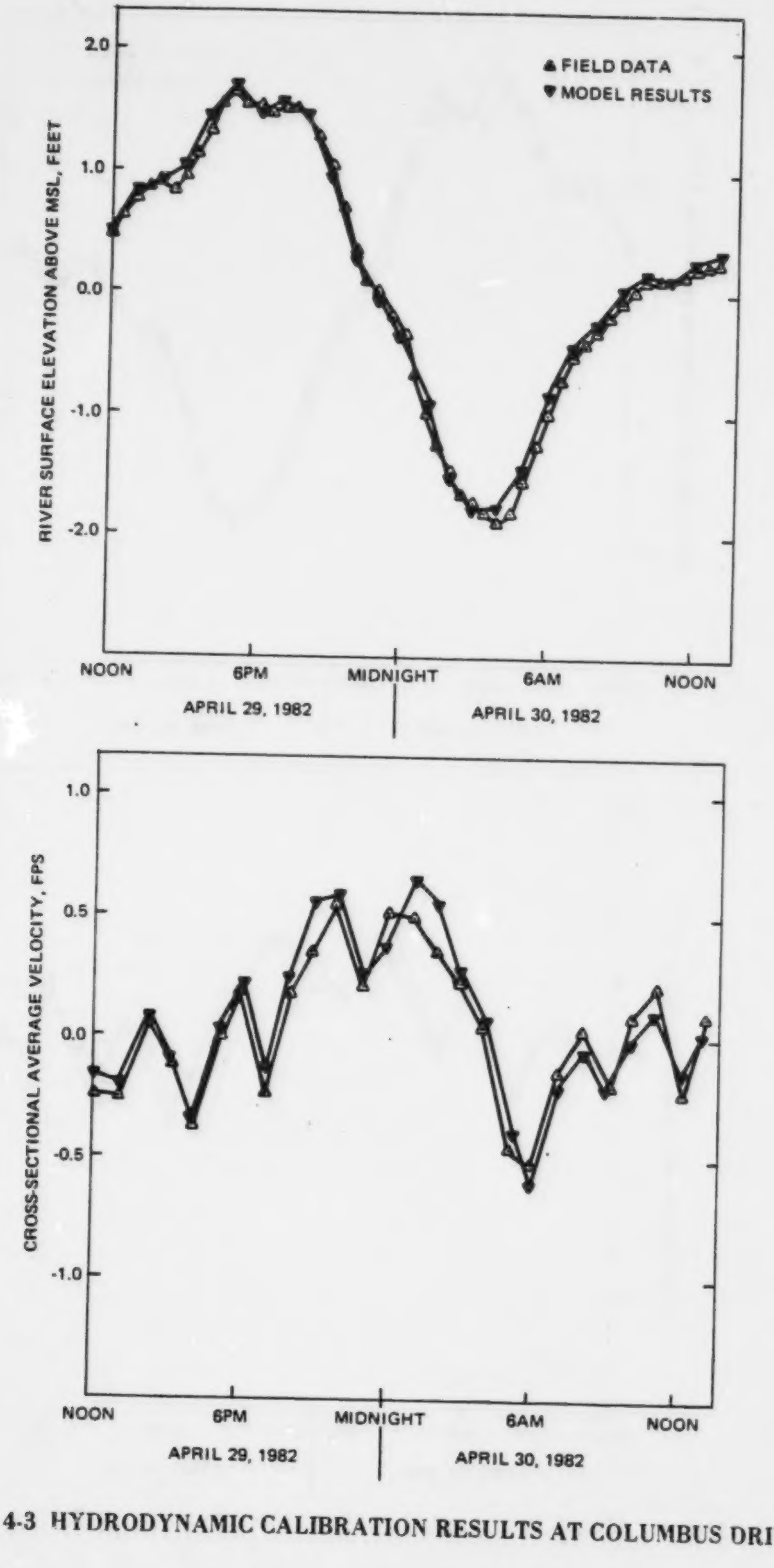


FIG. 4-3 HYDRODYNAMIC CALIBRATION RESULTS AT COLUMBUS DRIVE

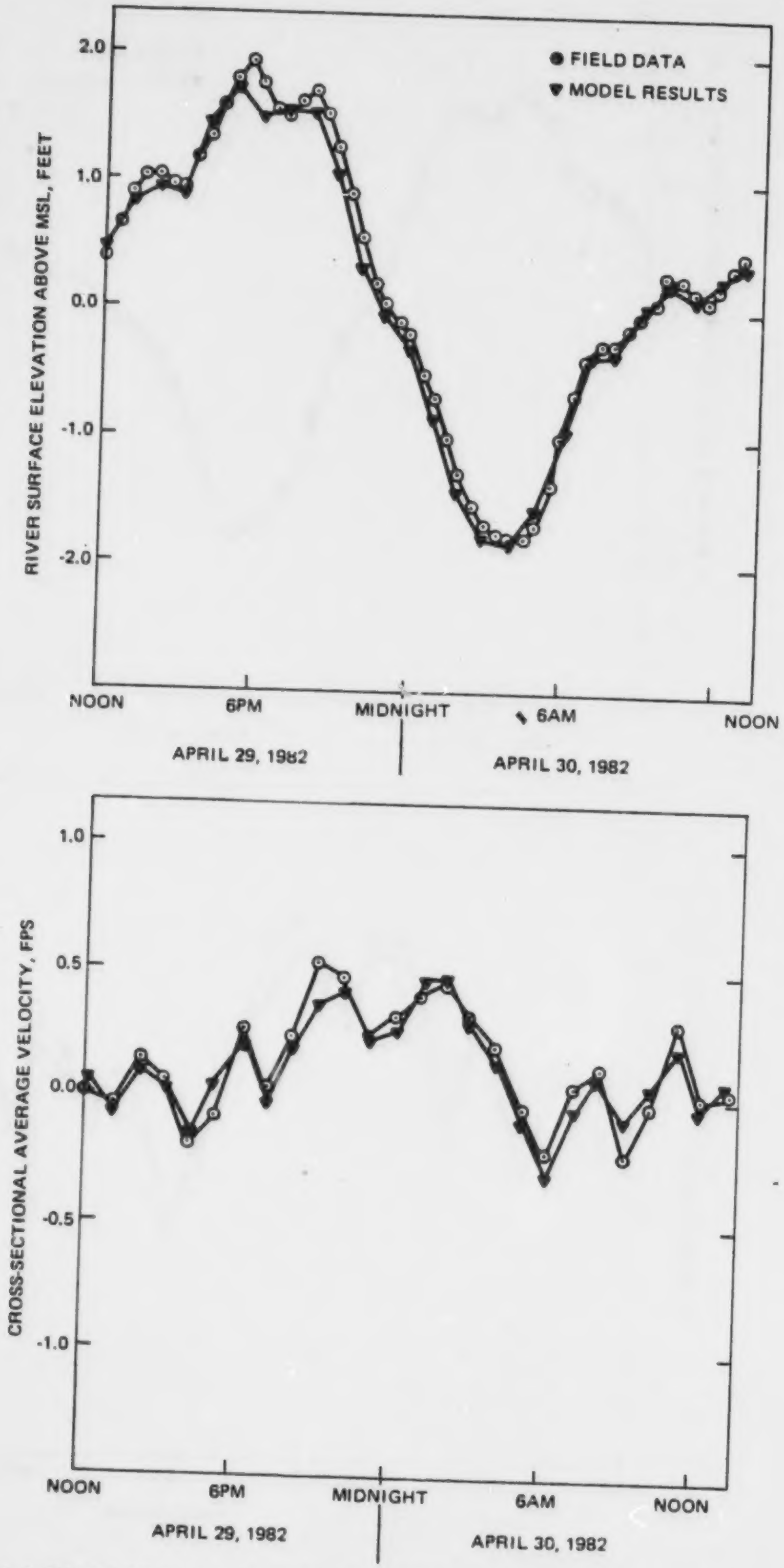


FIG. 4-4 HYDRODYNAMIC CALIBRATION RESULTS AT SLIGH AVENUE

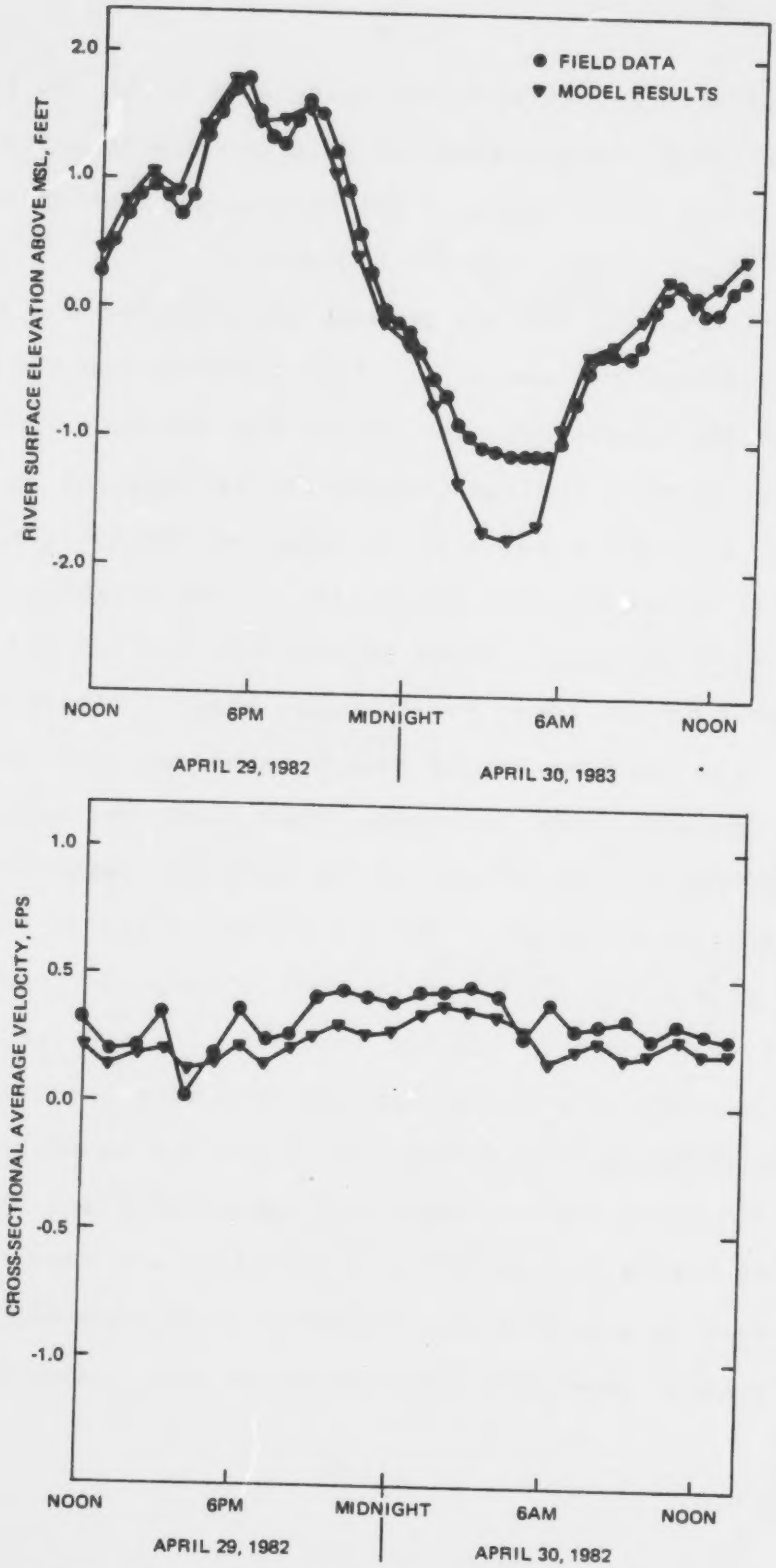


FIG. 4-5 HYDRODYNAMIC CALIBRATION RESULTS AT 22nd STREET

The dispersion parameter K was calculated to be 160 ft^2/sec. An ocean salinity concentration of 24.8 ppt was specified at Platt Street during flood tide. A salinity concentration of 0.0 ppt was specified at the upstream boundary.

Figures 4-6 and 4-7 present the measured and predicted salinity concentrations at all four stations for the April 1982 survey. The characteristics of the Bay boundary condition explained earlier in this Chapter can be observed at Platt Street. A constant salinity is input on the incoming tide, and the model determines the salinities on the outgoing tide.

Water Quality. Model calibration for BOD and DO variations in the lower Hillsborough River included the following steps. The sediment oxygen demand rates obtained from low flow conditions were input as oxygen sinks along the entire River, ranging from 2.6 gO_2/m^2/day in the upstream segments to 9.8 gO_2/m^2/day near the Bay. The dissolved oxygen reaeration rates ranged from 0.17 to 0.32/day at 25°C, based on variations of mean velocity and depth in various segments of the River. BOD and DO concentrations at the upstream boundary were specified based on data obtained at 22nd Street and at the Bay boundary based on data from Platt Street. The model inputs at Platt Street are shown in Figure 4-8 and model predictions and measured data for the remaining stations are presented in Figures 4-9 through 4-11. Model results show very good agreement with measured data.

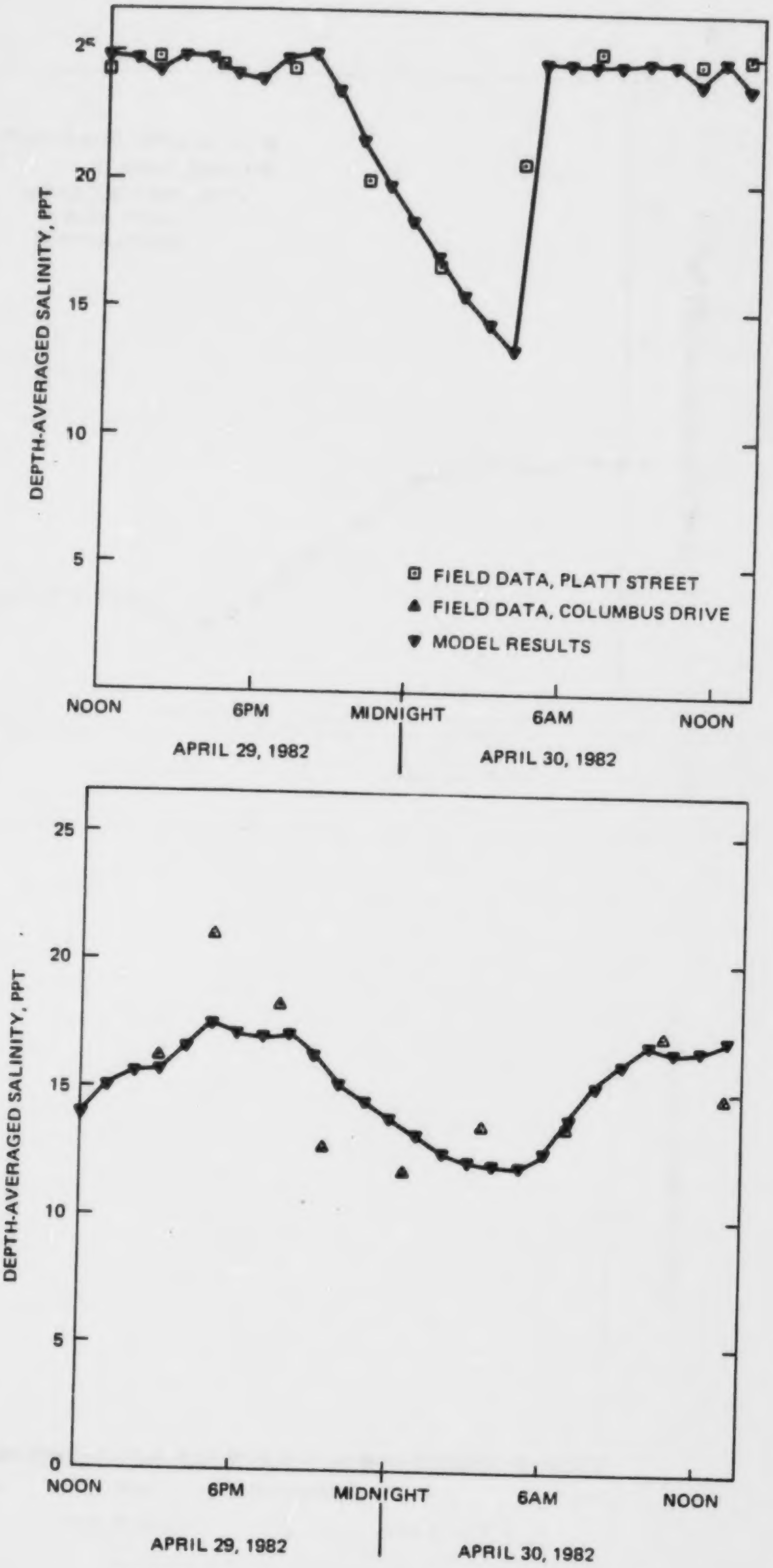


FIG. 4-6 SALINITY CALIBRATION RESULTS AT PLATT STREET AND COLUMBUS DRIVE

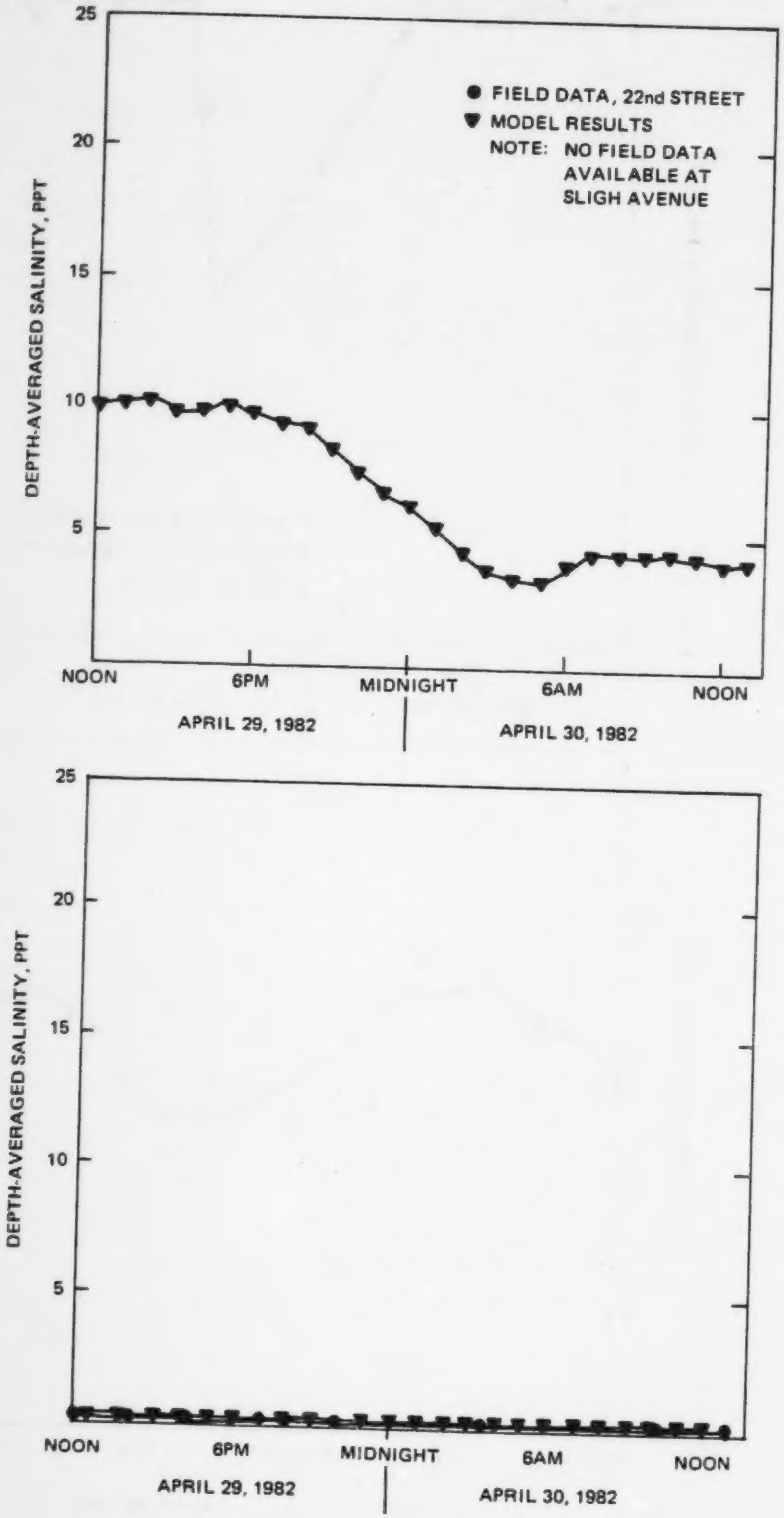


FIG. 4-7 SALINITY CALIBRATION RESULTS AT SLIGH AVENUE AND 22nd STREET

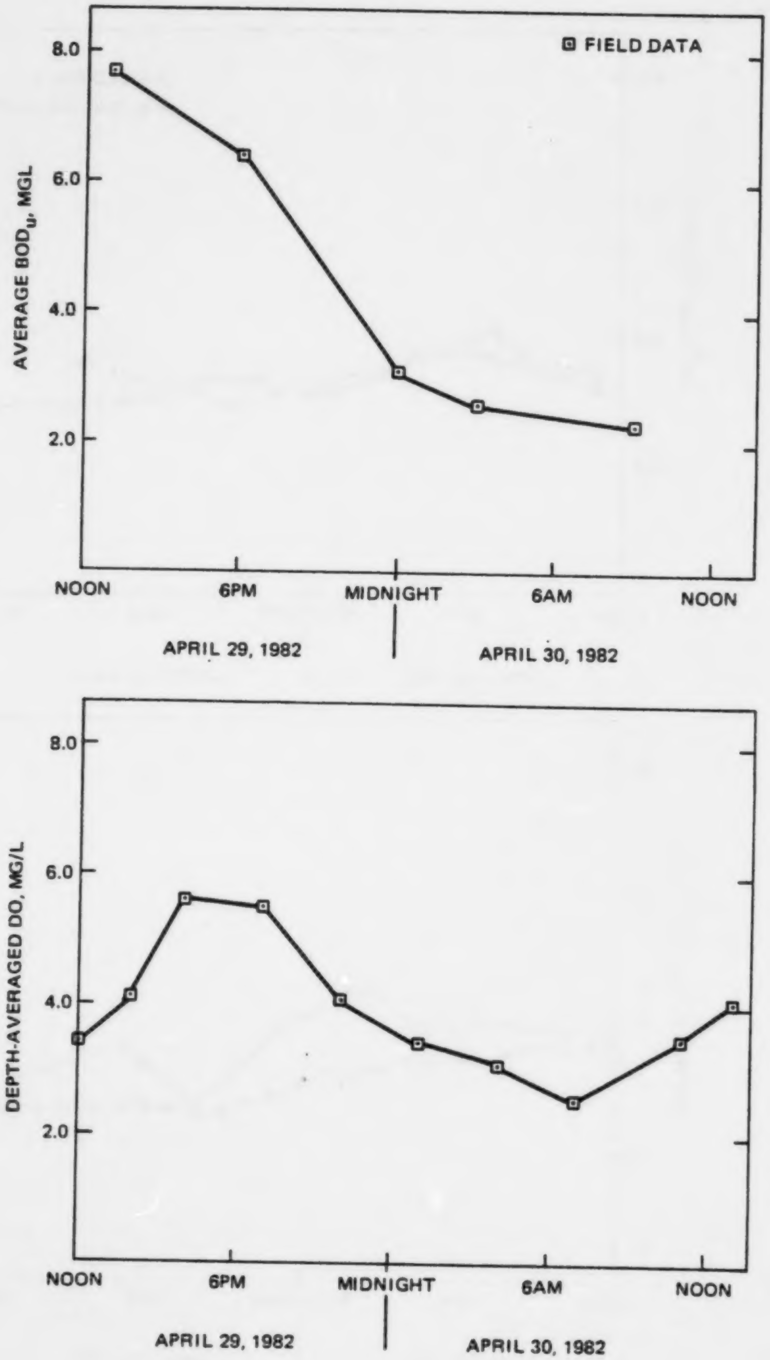


FIG. 4-8 TIME - VARYING BOUNDARY CONDITIONS OF BOD$_u$ AND DO AT PLATT STREET

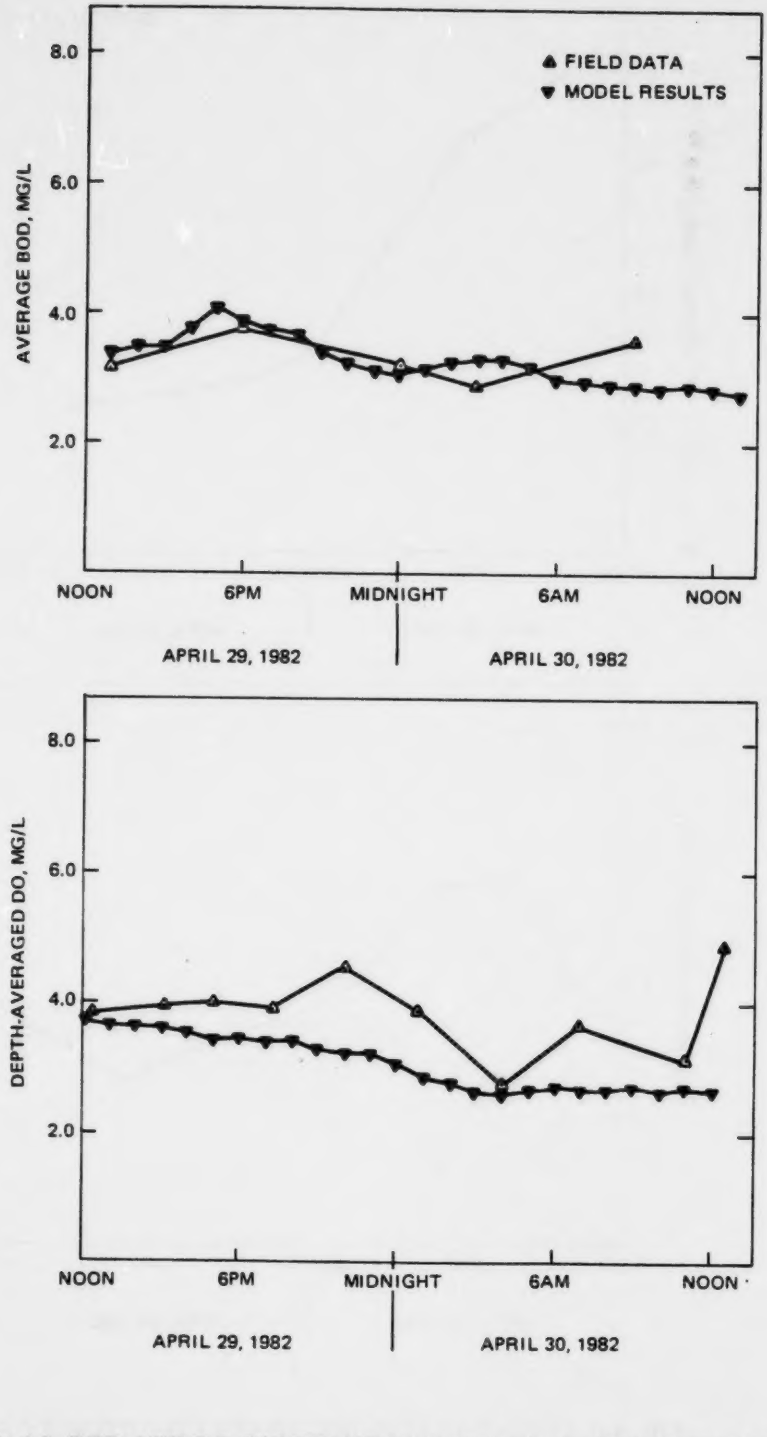


FIG. 4-9 BOD AND DO CALIBRATION RESULTS AT COLUMBUS DRIVE

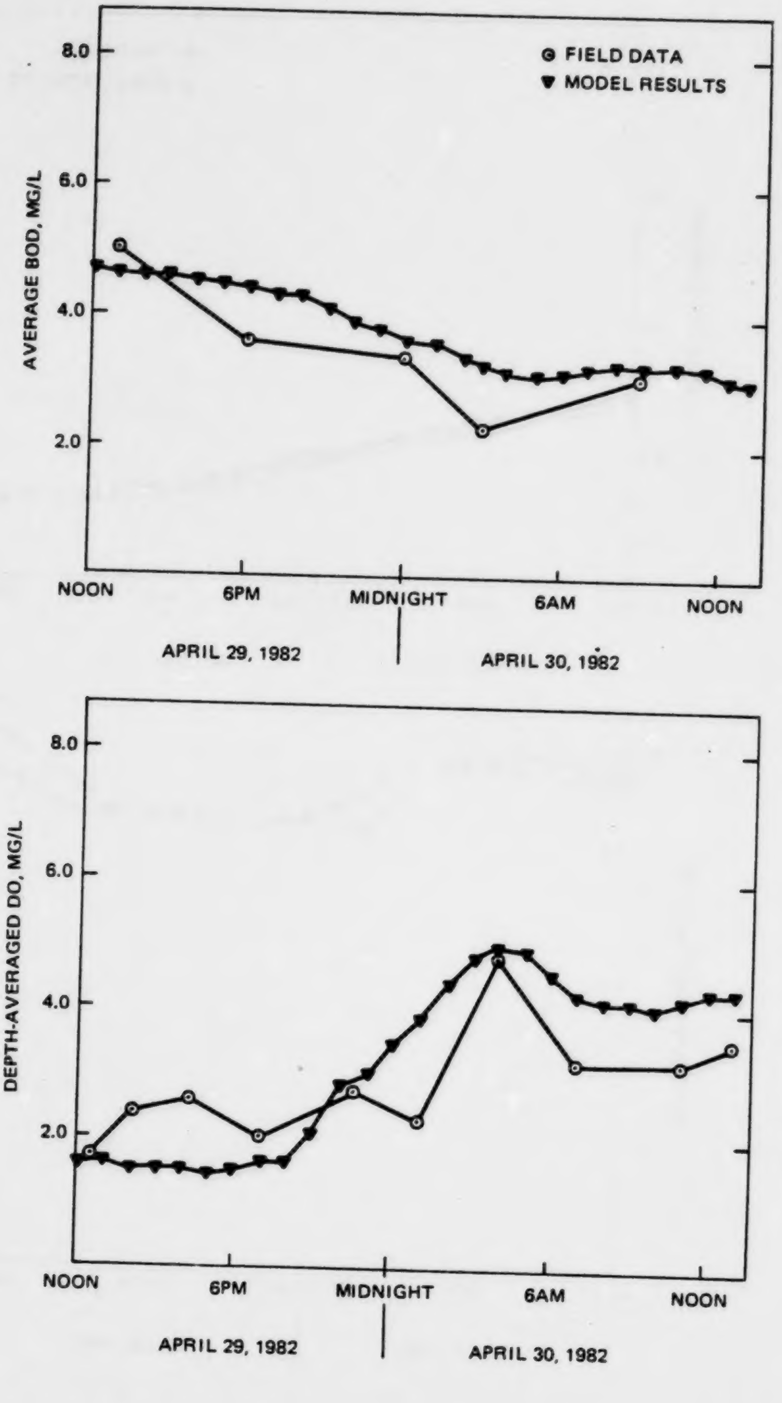


FIG. 4-10 BOD AND DO CALIBRATION RESULTS AT SLIGH AVENUE

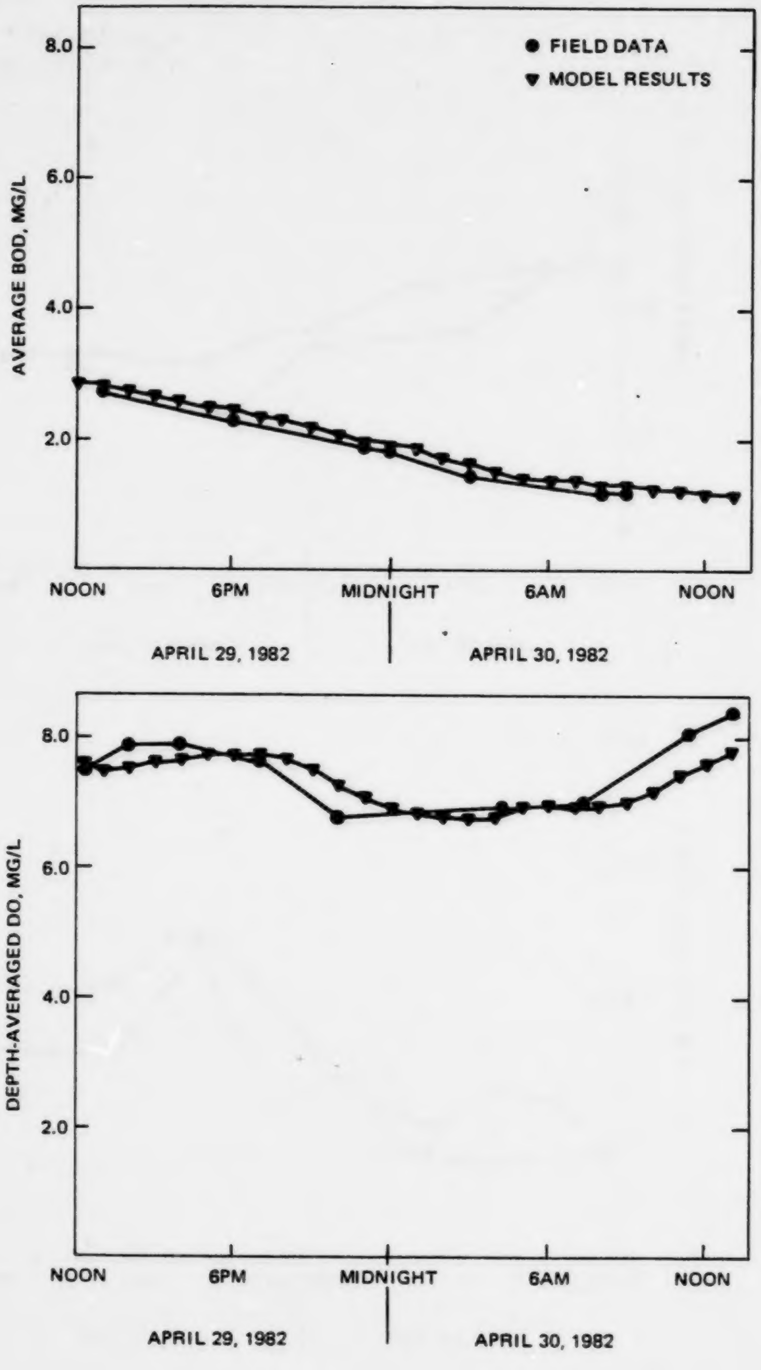


FIG. 4-11 BOD AND DO CALIBRATION RESULTS AT 22nd STREET

First Model Verification

The November 1982 survey was used for the first model verification. Thus, the impact of a storm event could be taken into account in the model simulations. A summary of model inputs is presented in Table 4-3. The hydrodynamics were simulated by the model using the tidal variation measured at Platt Street at the downstream boundary and time-varying freshwater releases (290 to 510 cfs) from the Reservoir at the upstream boundary. Both of these boundary conditions were presented earlier in Figure 3-8. The storm event that occurred near the start of this survey was input to the S/SWMM model and routed through all the drainage basins. The outflows from all the basins were input as lateral inflows to the lower Hillsborough River in the WQON model.

Hydrodynamic results are presented in Figures 4-12 through 4-15. Again, an excellent match is observed for velocities at Platt Street, Columbus Drive and both gage height and velocities at Sligh Avenue. The Columbus Drive tide gage was not working during this survey therefore only the predicted tidal variation is presented in Figure 4-13. In Figure 4-15, a significant discrepancy is observed between measured and predicted tide at 22nd Street. This is a result of the shoal areas in the River below this station. The difference between measured and predicted tides is greater here than observed in Figure 4-5 during the April 1982 survey, because of the higher freshwater flow (300 to 500 cfs) during the November 1982 survey. The measured and predicted velocities at this station match well despite the differences in river surface elevations.

TABLE 4-3. WQON MODEL INPUTS FOR FIRST VERIFICATION RUN

Parameter	Model Input
Tidal Variation at Bay Boundary	As measured at Platt Street on November 4-7, 1982.
Freshwater Flow from Reservoir	290-510 cfs as measured by USGS
Sulphur Springs Discharge	41.5 cfs
Salinity at Bay Boundary	20.0 ppt
Salinity at Upstream Boundary	0.0 ppt
Dispersion Parameter, K	228 ft^2/sec
BOD at Bay Boundary	As measured at Platt Street on November 4-7, 1982
BOD at Upstream Boundary	1.5 mg/l
BOD Loading in Stormwater Runoff	3.8 mg/l
DO at Bay Boundary	As measured at Platt Street on November 4-7, 1982
DO at Upstream Boundary	7.0 mg/l
DO of Stormwater Runoff	5.0 mg/l
BOD Decay Rate	0.23/day
DO Reaeration Rate	0.13 - 0.55/day
Sediment Oxygen Demand	1.1 - 3.6 gO_2/m^2/day

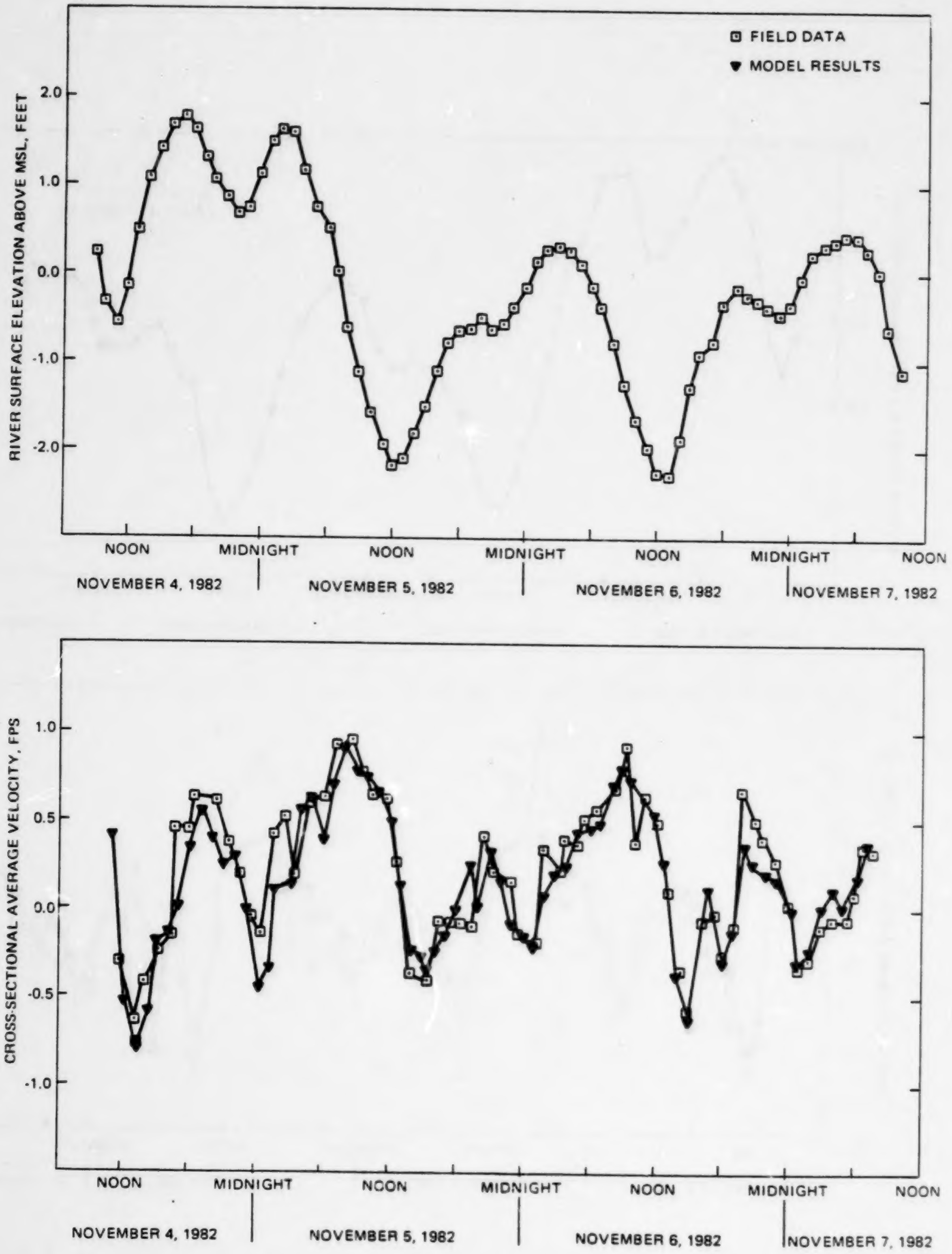


FIG. 4-12 HYDRODYNAMICS AT PLATT STREET - FIRST VERIFICATION

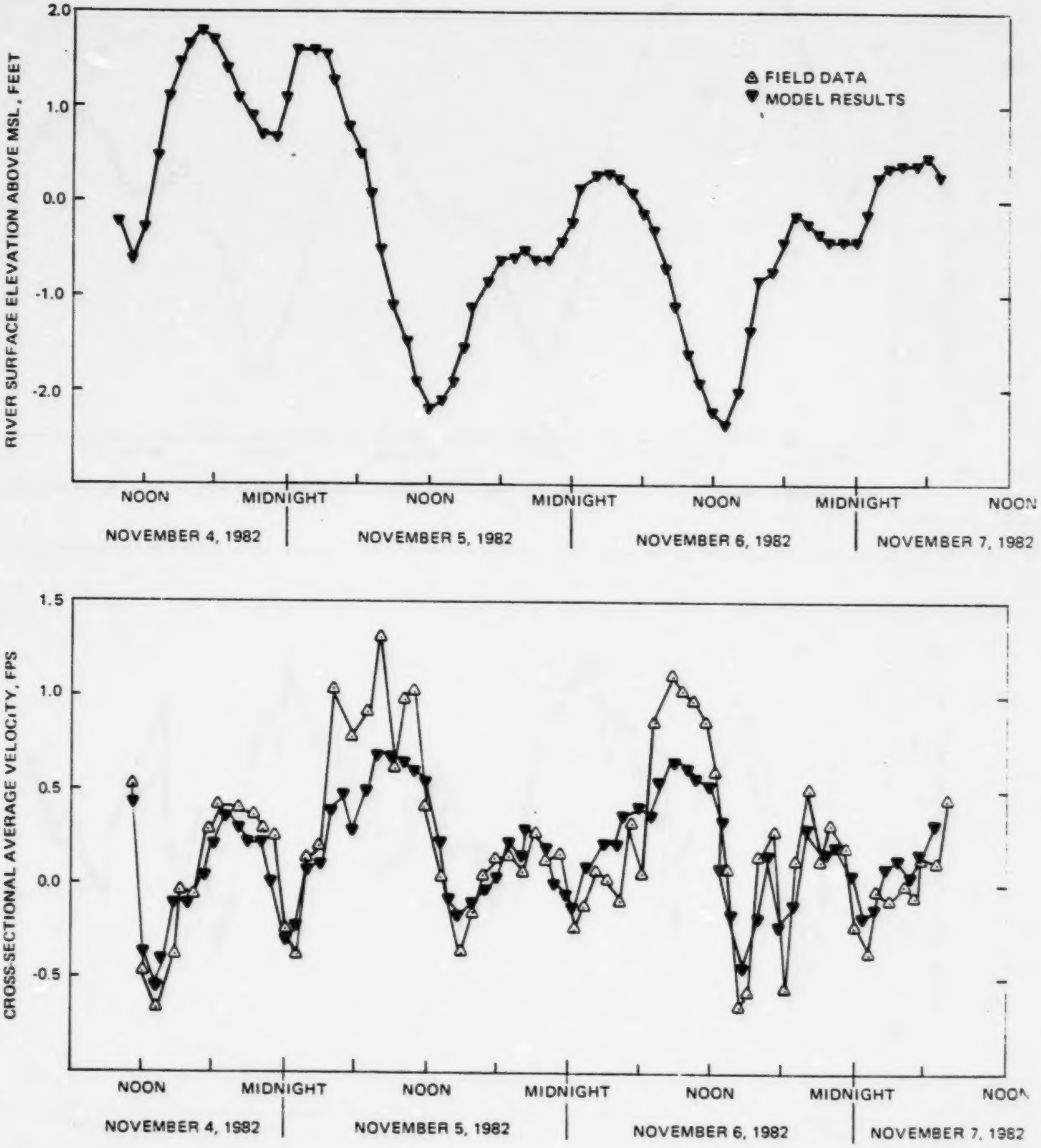


FIG. 4-13 HYDRODYNAMICS AT COLUMBUS DRIVE - FIRST VERIFICATION

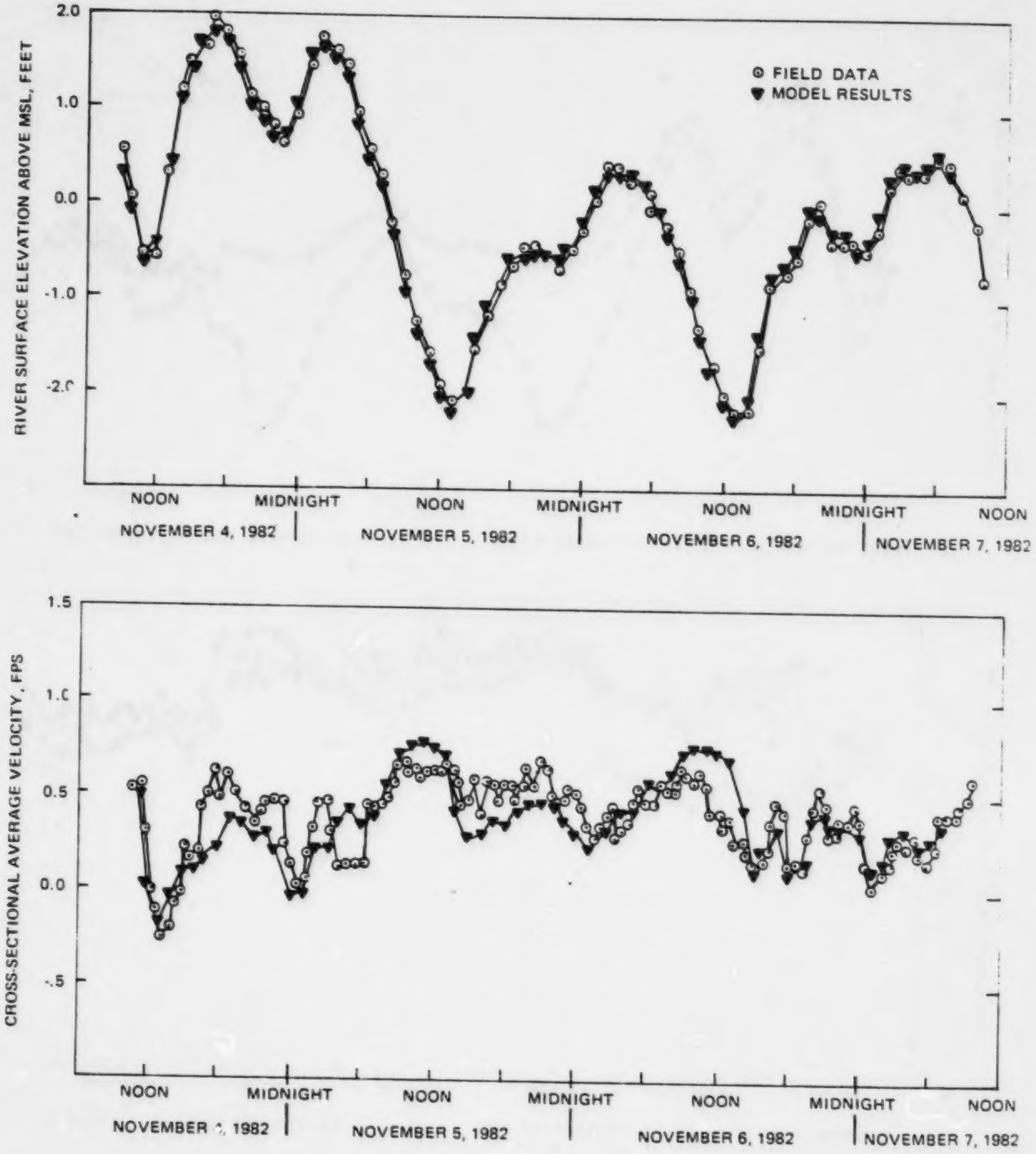


FIG. 4-14 HYDRODYNAMICS AT SLIGH AVENUE - FIRST VERIFICATION

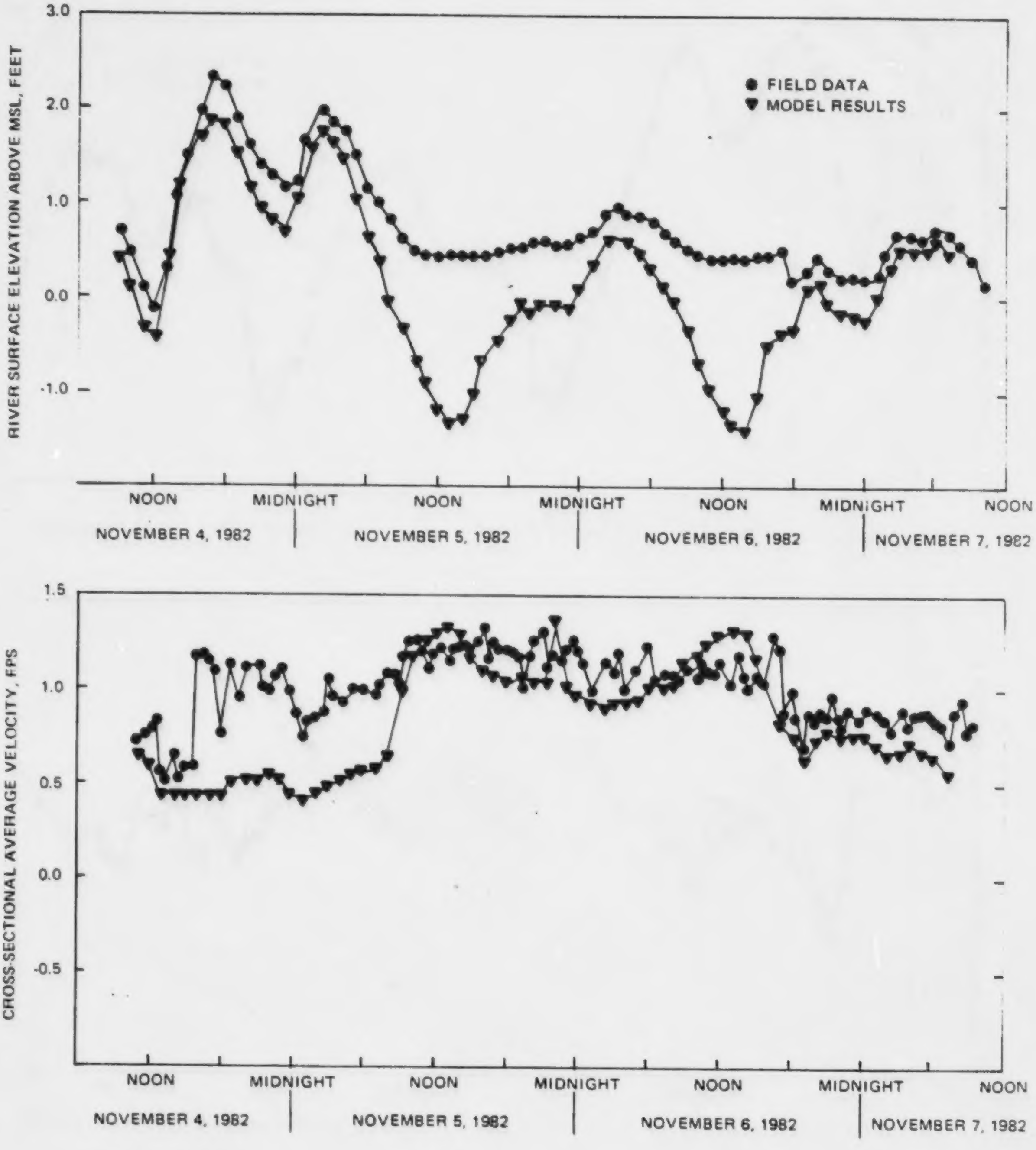


FIG. 4-15 HYDRODYNAMICS AT 22nd STREET - FIRST VERIFICATION

The results of salinity verification runs are presented in Figure 4-16. For this run a dispersion parameter K of 228 ft^2/sec was calculated based on an estuary number of 0.24, slightly higher than those of April 1982 survey due to increased freshwater discharge which resulted in higher velocities throughout the River. A Bay salinity concentration of 20 ppt was input to the model at Platt Street. The model predictions and field data measurements show good agreement at Platt Street and Columbus Drive. Measured data as well as model simulations showed no saline intrusion at Sligh Avenue and 22nd Street.

Water Quality. BOD and DO concentrations were also simulated by the model for the November survey. Since the sediment oxygen demand tests were carried out in both low and high flow conditions, the high flow SOD rates were used for this run. These varied from 1.1 gO_2/m^2/day in the vicinity of Sligh Avenue to 3.6 gO_2/m^2/day near the Bay. Reaeration rates were recalculated due to the increase in velocity in the River resulting from the higher Reservoir discharge. These varied from 0.13/day near the Bay boundary to 0.55/day in the vicinity of 22nd Street.

Time-varying BOD and DO concentrations were specified at the Bay boundary based on data obtained at Platt Street during the survey. A Bay concentration for BOD similar to salinity specifications could not be used because there was no apparent correlation bwteeen tide and BOD concentrations at Platt Street

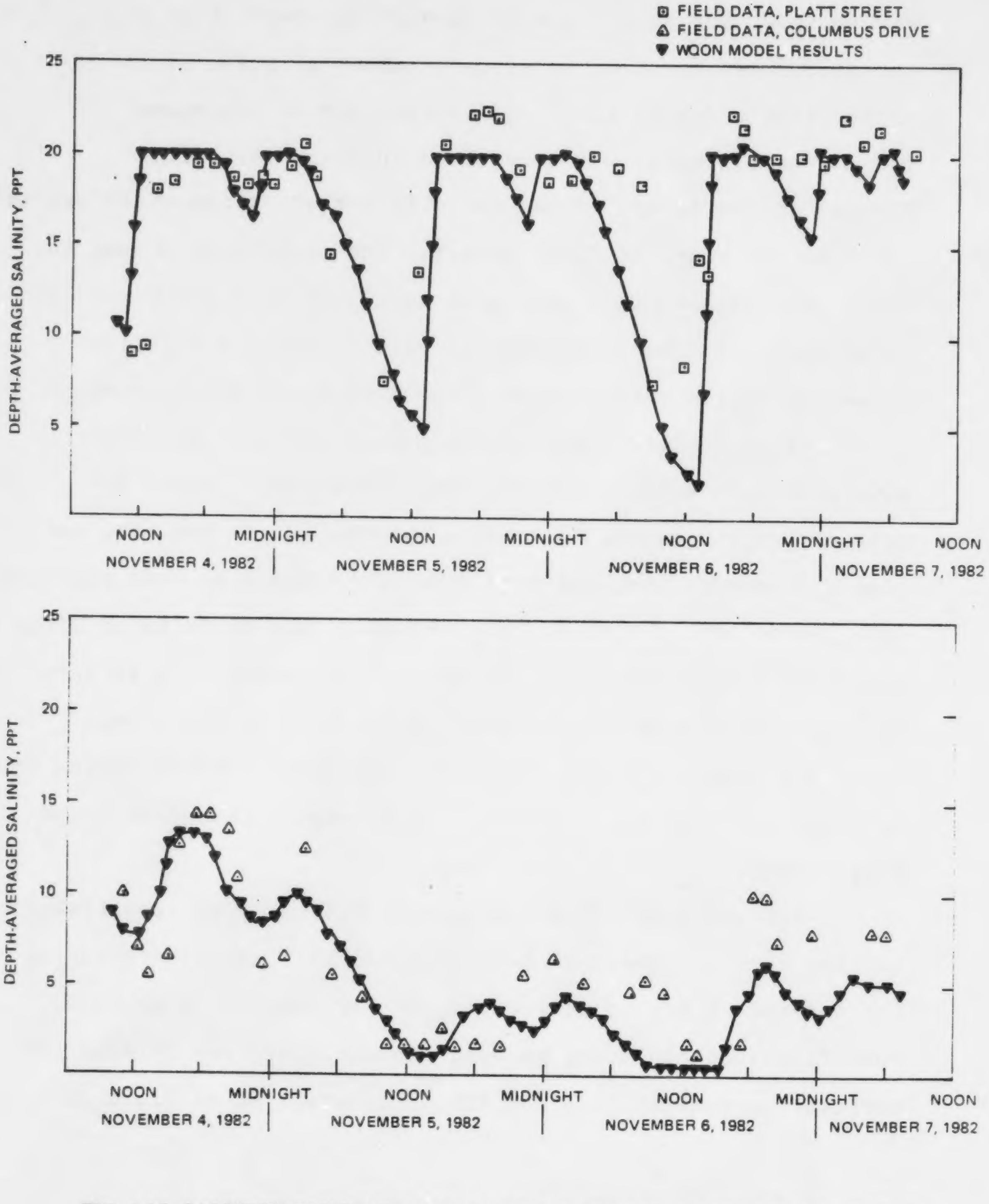


FIG. 4-16 SALINITY CONCENTRATIONS AT PLATT STREET AND COLUMBUS DRIVE FIRST VERIFICATION

(Figures 3-8 and 3-11). At the upstream boundary condition a DO concentration of 7.0 mg/l and a BOD of 1.5 mg/l were specified. The BOD_5 loadings from stormwater runoff were assumed to be 14 mg/l in all drainage basins. This was the average runoff concentration that had been observed during the Phase II study on areawide pollutant loadings (6). The model predicted concentrations of BOD and DO for this loading rate were much higher than the measured data indicated. The BOD_5 loading in the drainage areas was therefore reduced by one standard deviation to 3.8 mg/l. The results of this are presented in Figures 4-17 through 4-20 and appear to agree with the measured data. This indicates that the storm event occuring during this survey did not contribute large amounts of BOD to the River.

The predicted and measured DO concentrations for the low BOD loading at Columbus Drive, Sligh Avenue and 22nd Street are also presented in Figures 4-17 through 4-20. Although predicted DO concentrations agree well with field data at Sligh Avenue and 22nd Street, the fluctuation of DO concentrations measured at Columbus Drive is not reflected in the model results. In Figure 3-10 the DO concentrations at Columbus Drive and Platt Street seem to follow a similar pattern that roughly corresponds to the variation in tides. Due to the freshwater flow of 300 to 500 cfs during this survey, the saline wedge is in the vicinity of Columbus Drive as seen in Figure 3-9. Only three vertical measurements of DO were obtained at all stations during this survey. The averaged DO values fluctuated significantly,

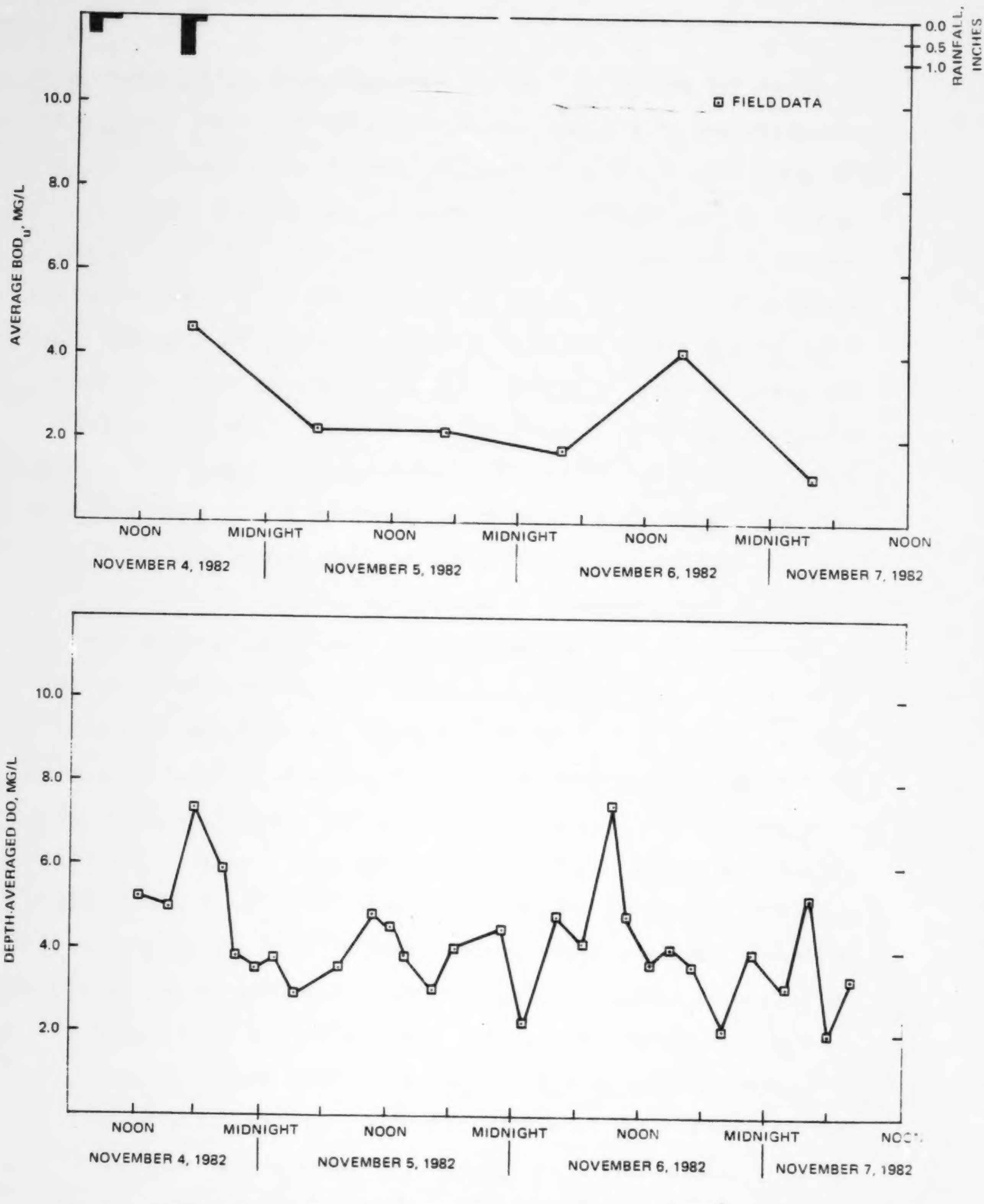


FIG. 4-17 TIME-VARYING BOUNDARY CONDITIONS FOR BOD$_u$ AND DO AT PLATT STREET FIRST VERIFICATION

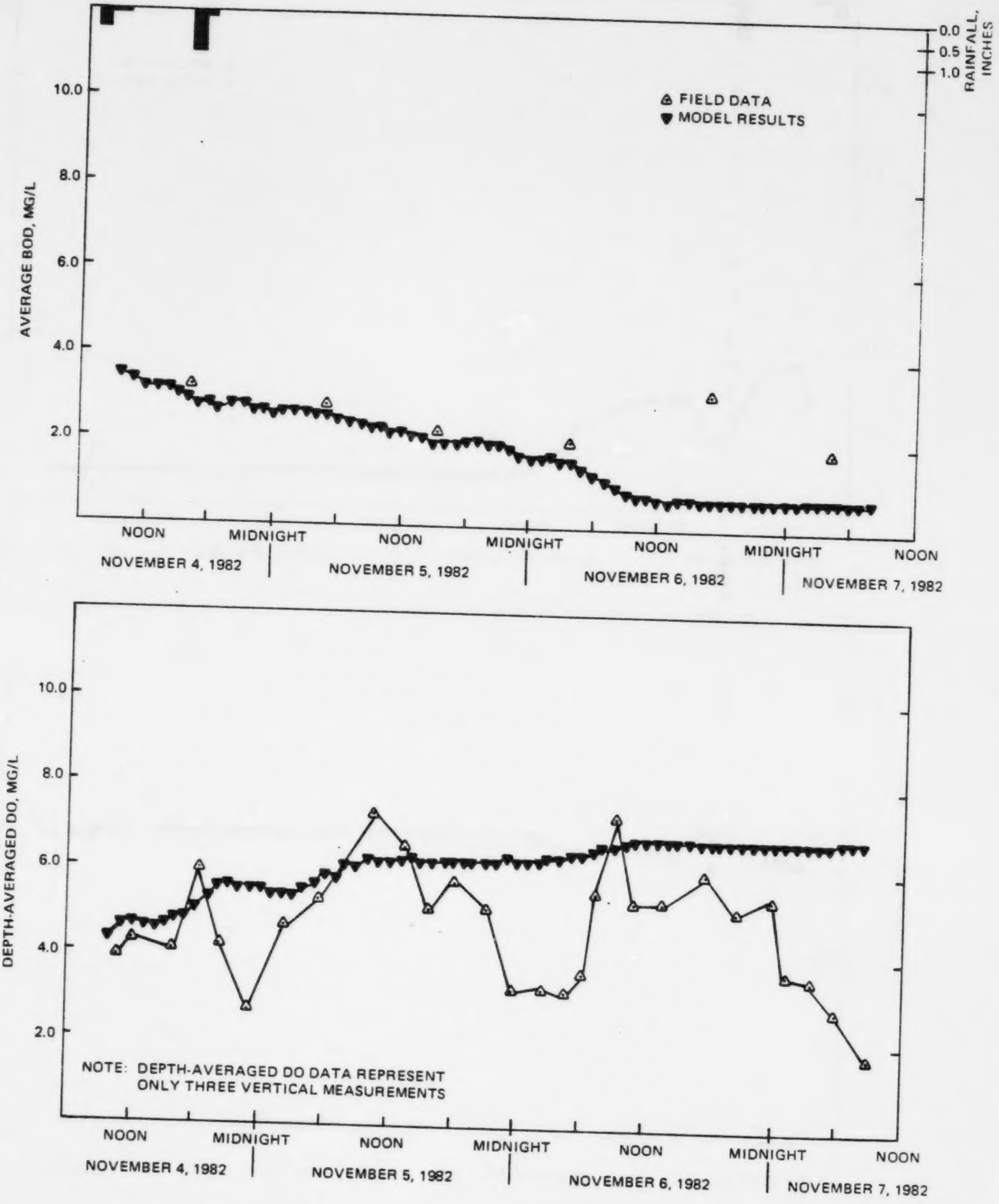


FIG. 4-18 BOD AND DO CONCENTRATIONS AT COLUMBUS DRIVE
FIRST VERIFICATION

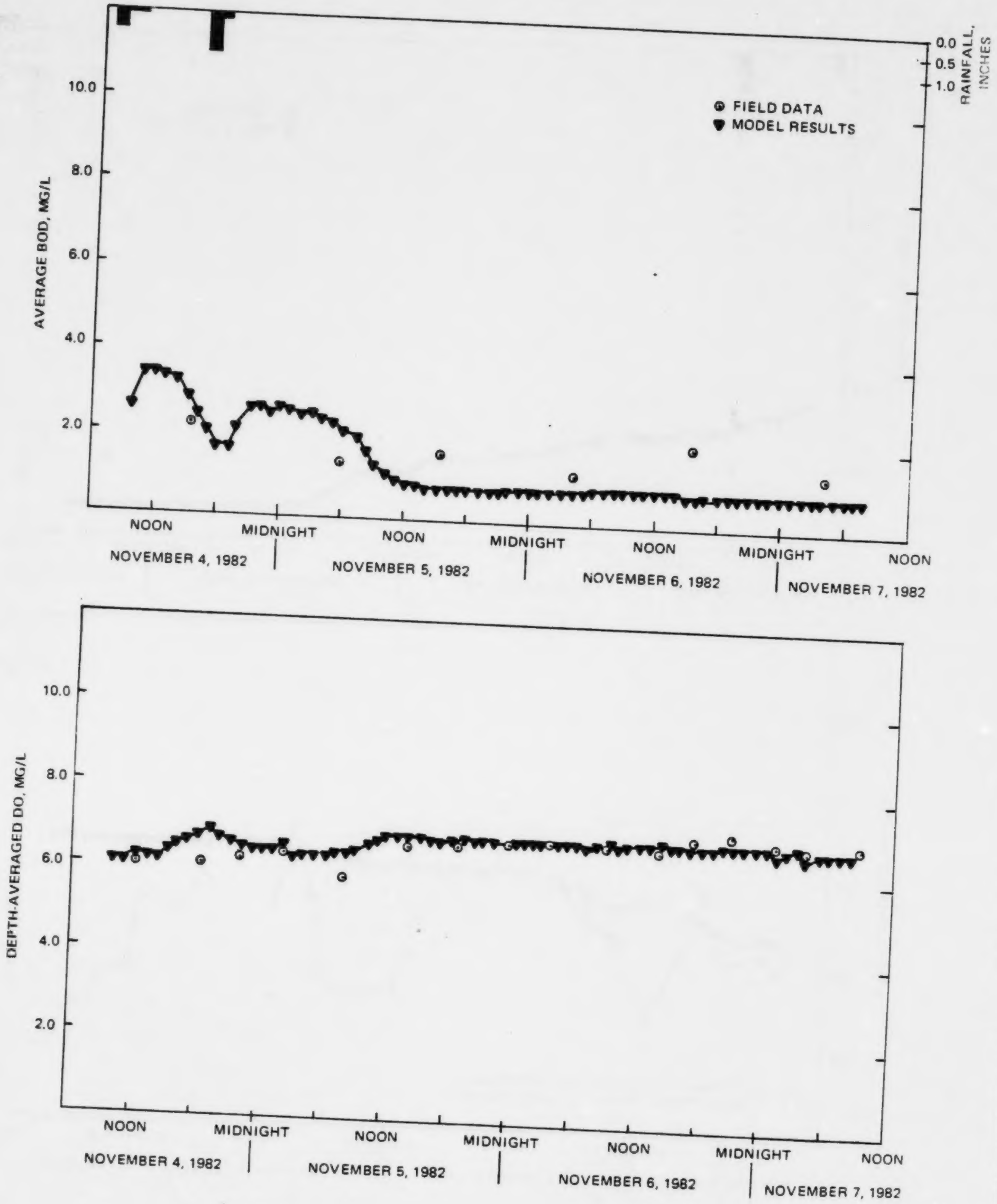


FIG. 4-19 BOD AND DO CONCENTRATIONS AT SLIGH AVENUE
FIRST VERIFICATION

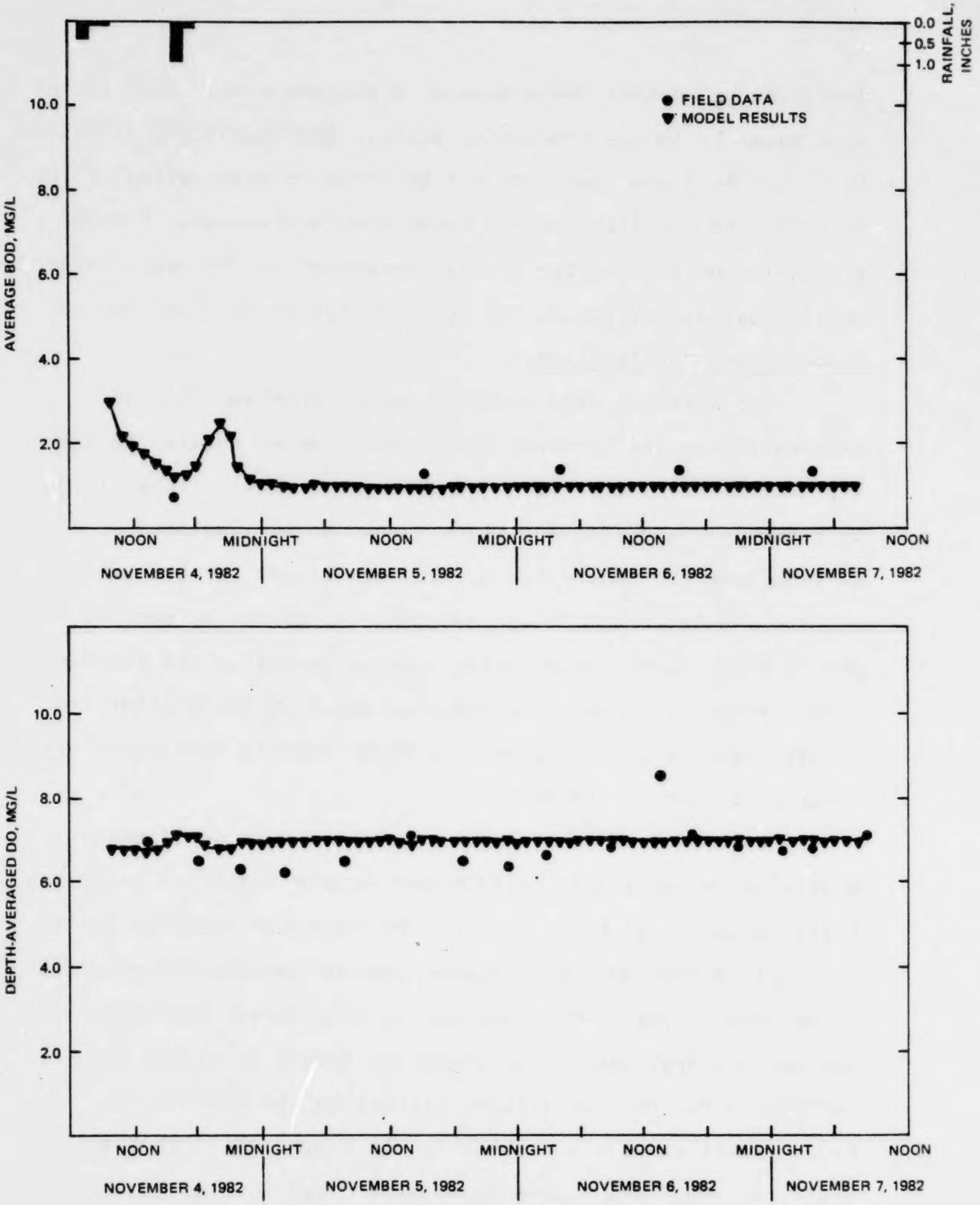


**FIG. 4-20 BOD AND DO CONCENTRATIONS AT 22nd STREET
FIRST VERIFICATION**

depending on whether the mid-depth measurement was taken in the salt layer or in the freshwater layer. The field data presented in Figure 4-18 are therefore not an accurate description of the DO levels in the water column under such conditions. Further discussion on this matter will be presented in the next Chapter on vertical variations in the lower Hillsborough River estuary.

Second Model Verification

The November 1982 synoptic survey provided limited information on the vertical variation of water quality in the vicinity of the saline wedge near Columbus Drive. In addition, this survey began during a storm event, presenting some difficulties for specifying initial conditions for the water quality simulations. It was decided, therefore, to perform a second model verification using data collected in the February 1983 survey. A large storm occurred about 20 hours after the survey began, therefore pre-storm water quality conditions are clearly defined in the data.

A summary of model inputs for the second verification is presented in Table 4-4. Hydrodynamics were simulated using the tidal variation at Platt Street. No discharge occurred at the Reservoir except during a two-hour period immediately after the storm event. The storm event during this survey was routed through all drainage basins using the S/SWMM model and the outflows were input as lateral inflows in the WQON model. Hydrodynamic results are presented in Figures 4-21 through 4-24. An excellent agreement between field data and model results is seen in these Figures. There is slight variation

TABLE 4-4. WQON MODEL INPUTS FOR SECOND VERIFICATION RUN

Parameter	Model Input
Tidal Variation at Bay Boundary	As measured at Platt Street on February 1-4, 1983
Freshwater Flow from Reservoir	355 cfs from 9-11 AM on February 2, 1983
Sulphur Springs Discharge	41.5 cfs
Salinity at Bay Boundary	25.0 ppt before storm, 24.0 after storm
Salinity at Upstream Boundary	4.5 ppt before storm, 0.0 ppt after storm
Dispersion Parameter, K	57 ft^2/sec
BOD at Bay Boundary	As measured at Platt Street on February 1-4, 1983
BOD at Upstream Boundary	As measured at 22nd Street on February 1-4, 1983
DO at Bay Boundary	As measured at Platt Street on February 1-4, 1983
DO at Upstream Boundary	As measured at 22nd Street on February 1-4, 1983
Fecal Coliform at Bay Boundary	As measured at Platt Street on February 1-4, 1983
Fecal Coliform at Upstream Boundary	As measured at 22nd Street on February 1-4, 1983
BOD decay rate	0.23/day
DO reaeration rate	0.11 - 0.18/day
Fecal Coliform decay rate	2.0/day
Sediment Oxygen Demand	2.6 - 9.8 gO_2/m^2/day

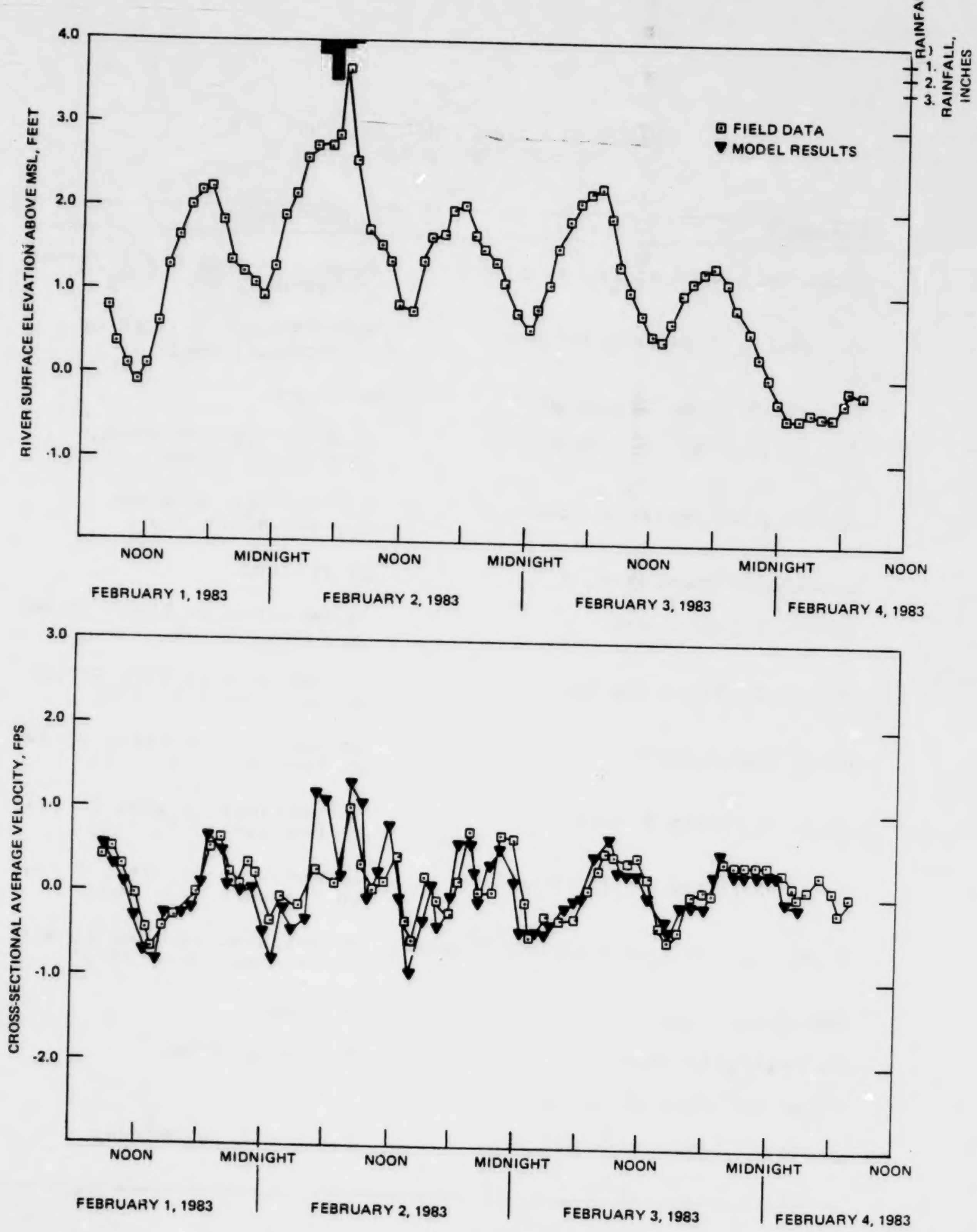


FIG. 4-21 HYDRODYNAMICS AT PLATT STREET - SECOND VERIFICATION

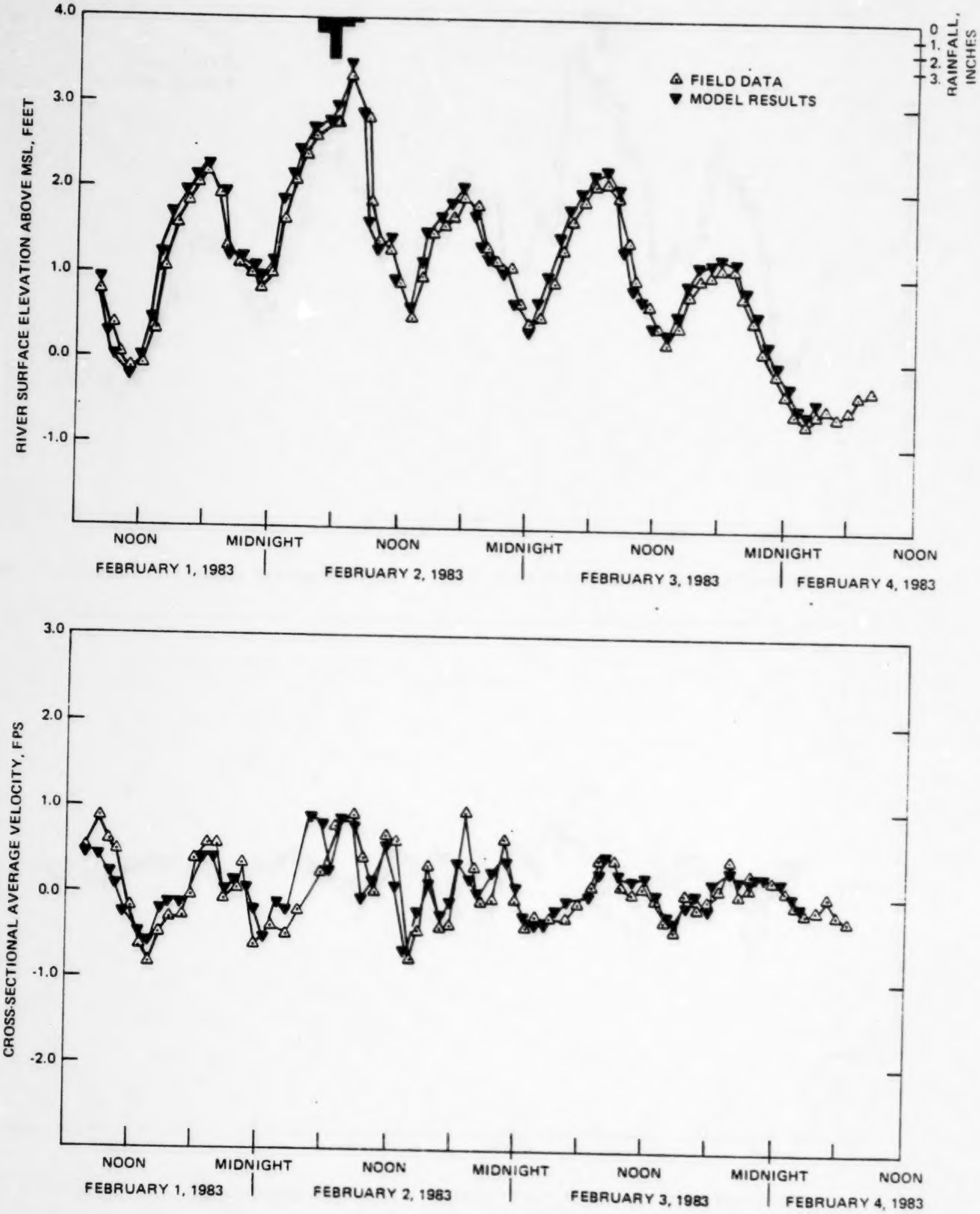


FIG. 4-22 HYDRODYNAMICS AT COLUMBUS DRIVE - SECOND VERIFICATION

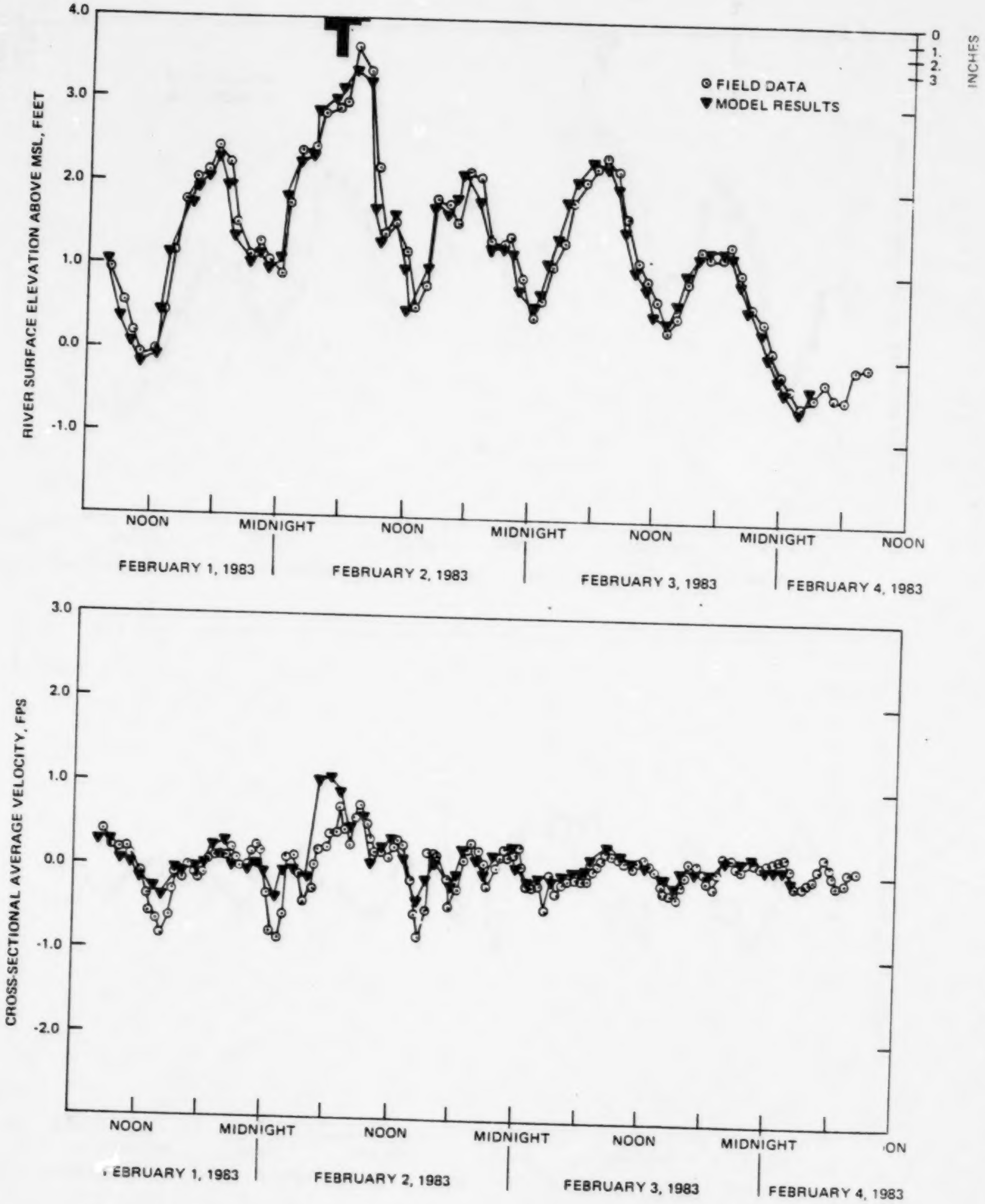
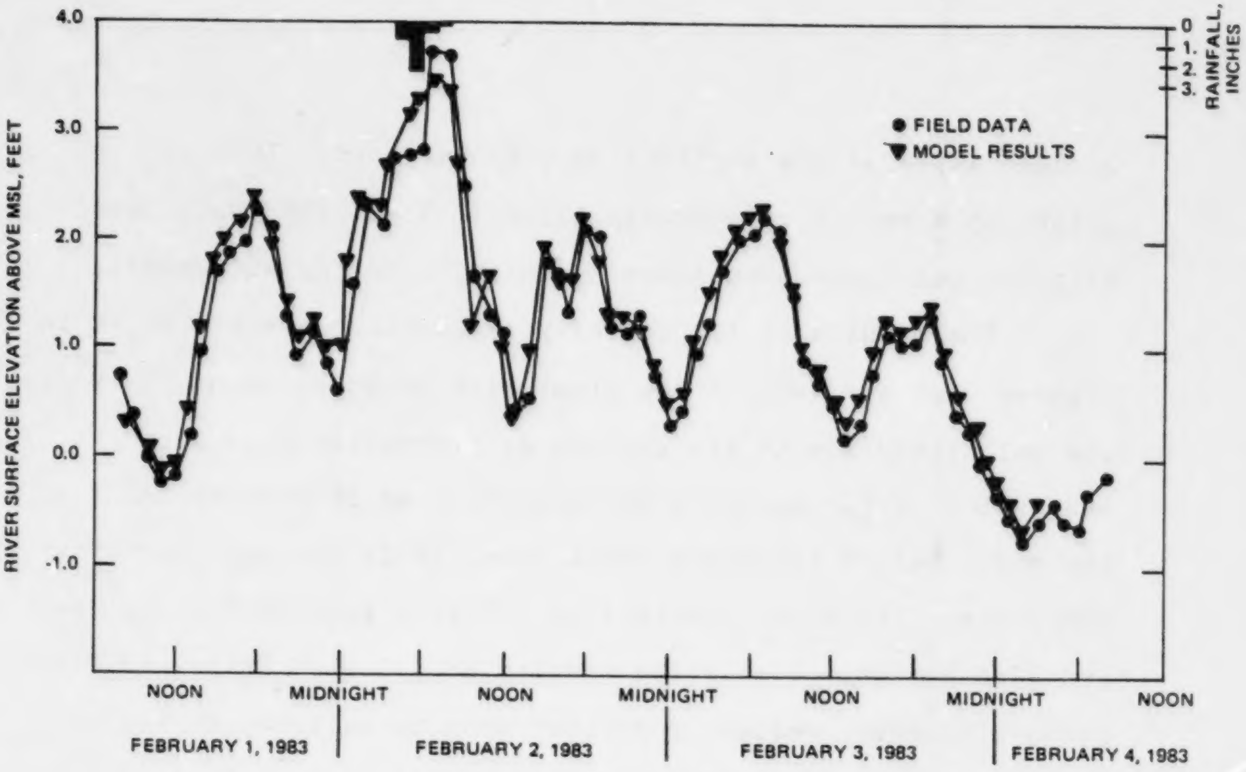


FIG. 4-23 HYDRODYNAMICS AT SLIGH AVENUE - SECOND VERIFICATION



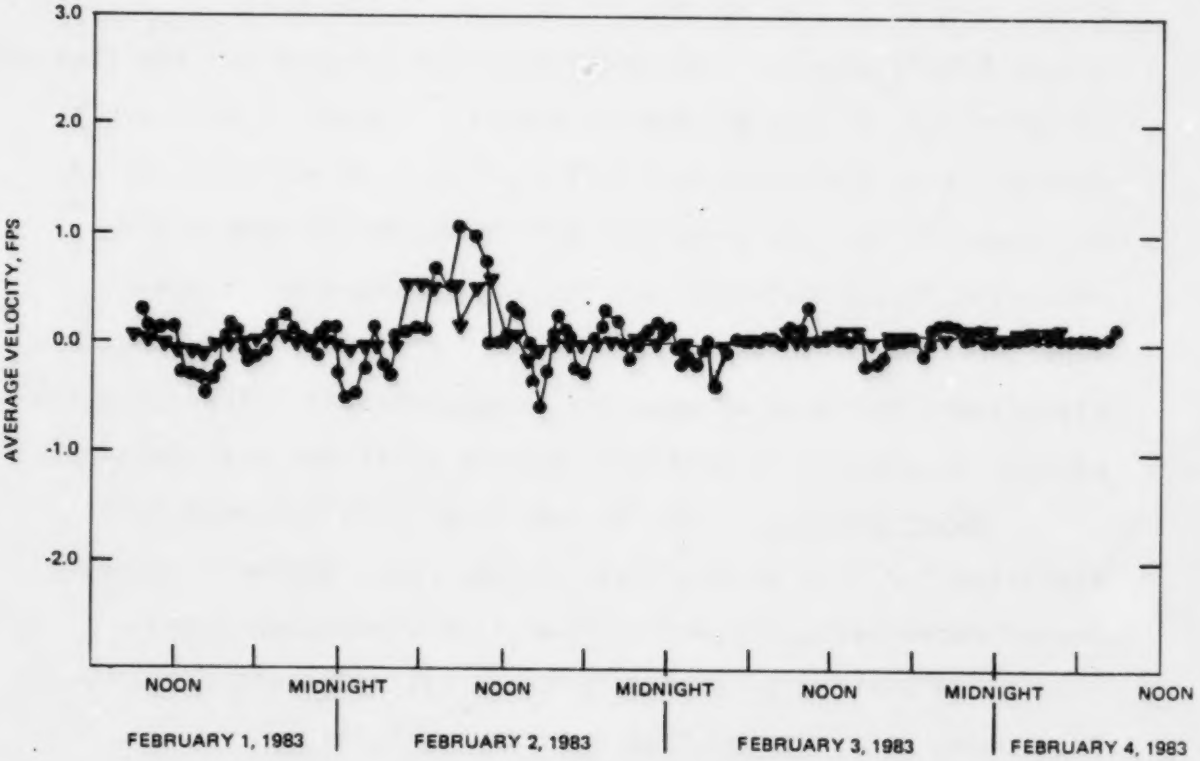


FIG. 4-24 HYDRODYNAMICS AT 22nd STREET - SECOND VERIFICATION

in velocities at all stations during the storm. This is primarily a result of approximations in the S/SWMM calculated outflows and their subsequent translation to the WQON model.

The results of the salinity simulations are presented in Figures 4-25 and 4-26. A low dispersion parameter K of 57 ft^2/sec was calculated due to the absence of freshwater flow from the Reservoir. A Bay salinity concentration of 25 ppt was input to the model before the storm and a value of 24 ppt was used after the storm. The model predictions are very good at Platt Street and 22nd Street. Simulation results at Columbus Drive and Sligh Avenue, however, reflect a greater drop in salinity during and after the storm than reflected in the field data. This is a direct result of the stormwater inflows to the River as predicted by the S/SWMM model. This model does not account for the time of concentration of the stormwater runoff. Rather, a rain event results in an instantaneous outflow from each subarea. In all but three or four subareas the entire volume of runoff was predicted to occur during the four-hour period of rainfall. Superimposing this runoff on the River simulation resulted in a significant decrease of salinity concentrations. These did not recover as quickly in upstream reaches as at the Bay boundary.

Water Quality. BOD, DO and fecal coliform were also simulated for this second verification run. Sediment oxygen demand rates reflected dry weather (low freshwater flow) conditions such as were used in the April 1982 calibration run. Reaeration rates varied from 0.11/day to 0.18/day.

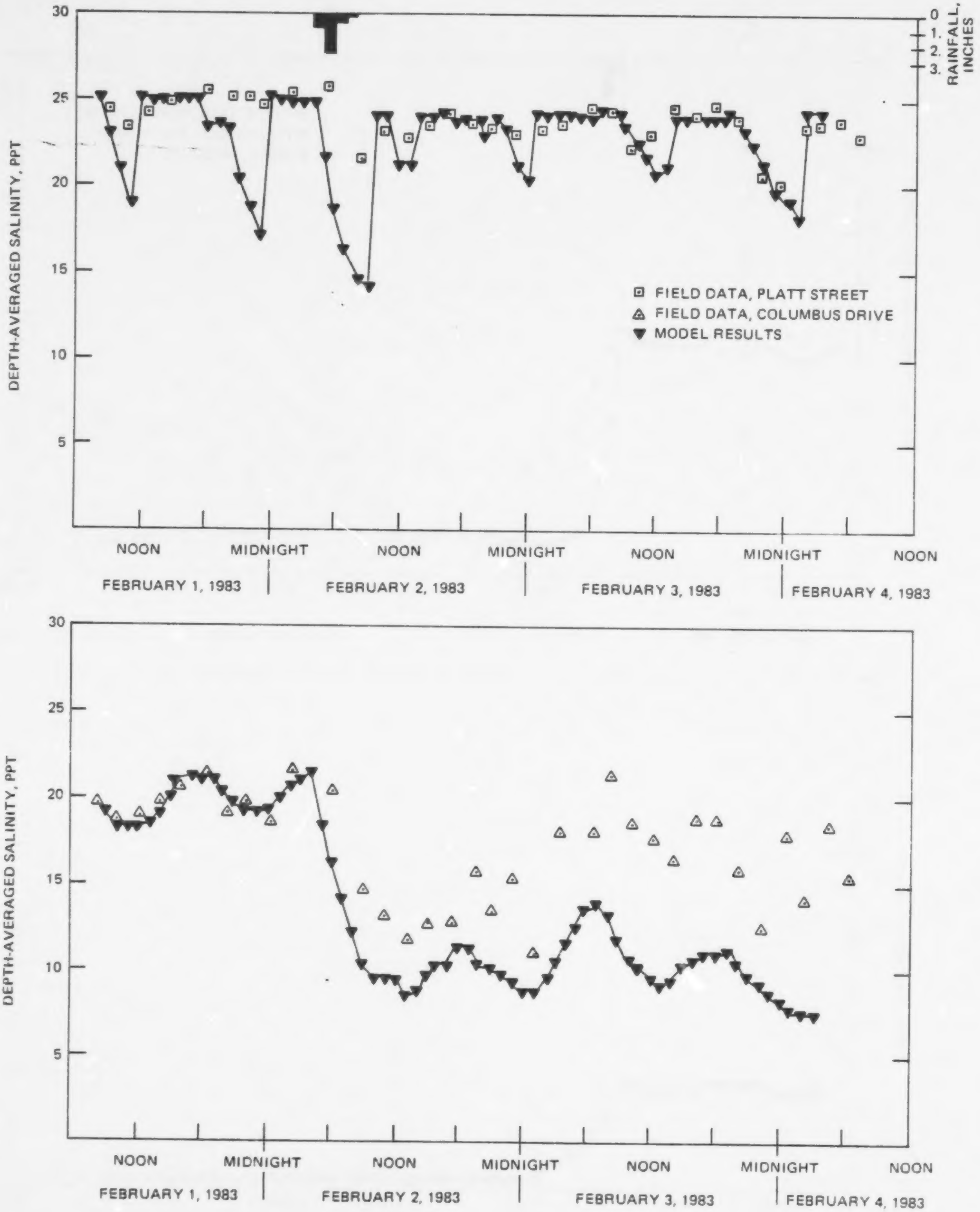


FIG. 4-25 SALINITY CONCENTRATIONS AT PLATT STREET AND COLUMBUS DRIVE SECOND VERIFICATION

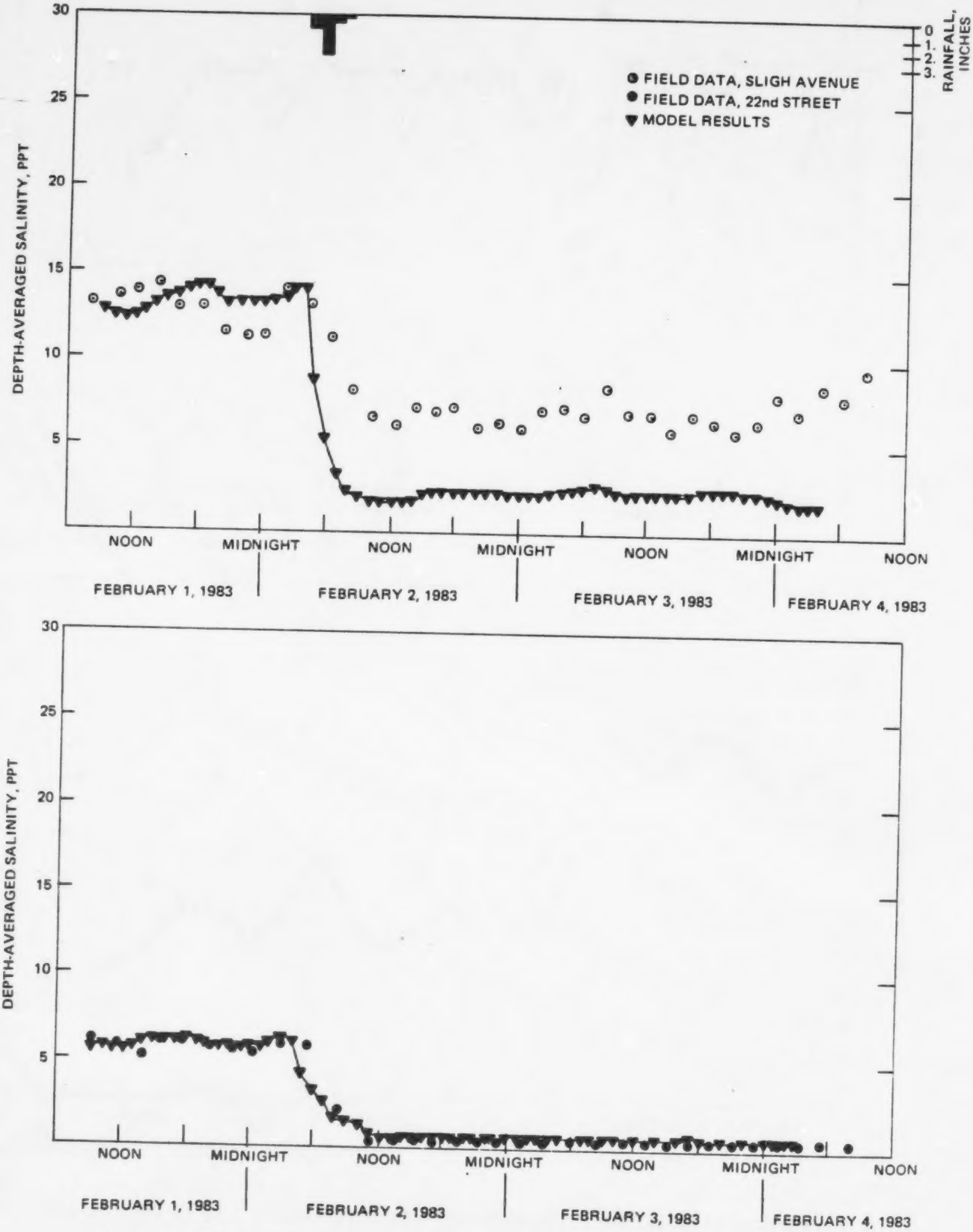


FIG. 4-26 SALINITY CONCENTRATIONS AT SLIGH AVENUE AND 22nd STREET SECOND VERIFICATION

BOD and DO boundary conditions at Platt Street are presented in Figure 4-27. Model predictions are presented in Figures 4-28 through 4-30. As in the November survey, a low BOD_5 concentration of 3.8 mg/l in the stormwater runoff was used and appears to best match available data points. The model-predicted DO levels at 22nd Street do not match field data before the storm begins. Attempts were not made to model the algal activity that caused the high dissolved oxygen levels at this station. Model simulations of DO levels generally reflect very good agreement with field data.

Fecal coliform concentrations of 25,400 MPN/100 ml were assumed for stormwater runoff (6). A decay rate of 2.0/day was found to provide the best agreement of model predictions with field data. The boundary coliform concentrations at Platt Street and model predictions at Columbus Drive are presented in Figure 4-31. Figure 4-32 presents model predictions at Sligh Avenue and 22nd Street. Again, model results reflect very good agreement with field data.

Summary

The WQON model has been successfully calibrated and verified for hydrodynamics, salinity and water quality. The data collected during the synoptic surveys as well as supplementary data obtained for stream characteristics, bathymetry, sediment oxygen demand, and velocity rating curves provided the necessary information to accurately represent the lower Hillsborough River with a numerical model. Assessments of future River conditions

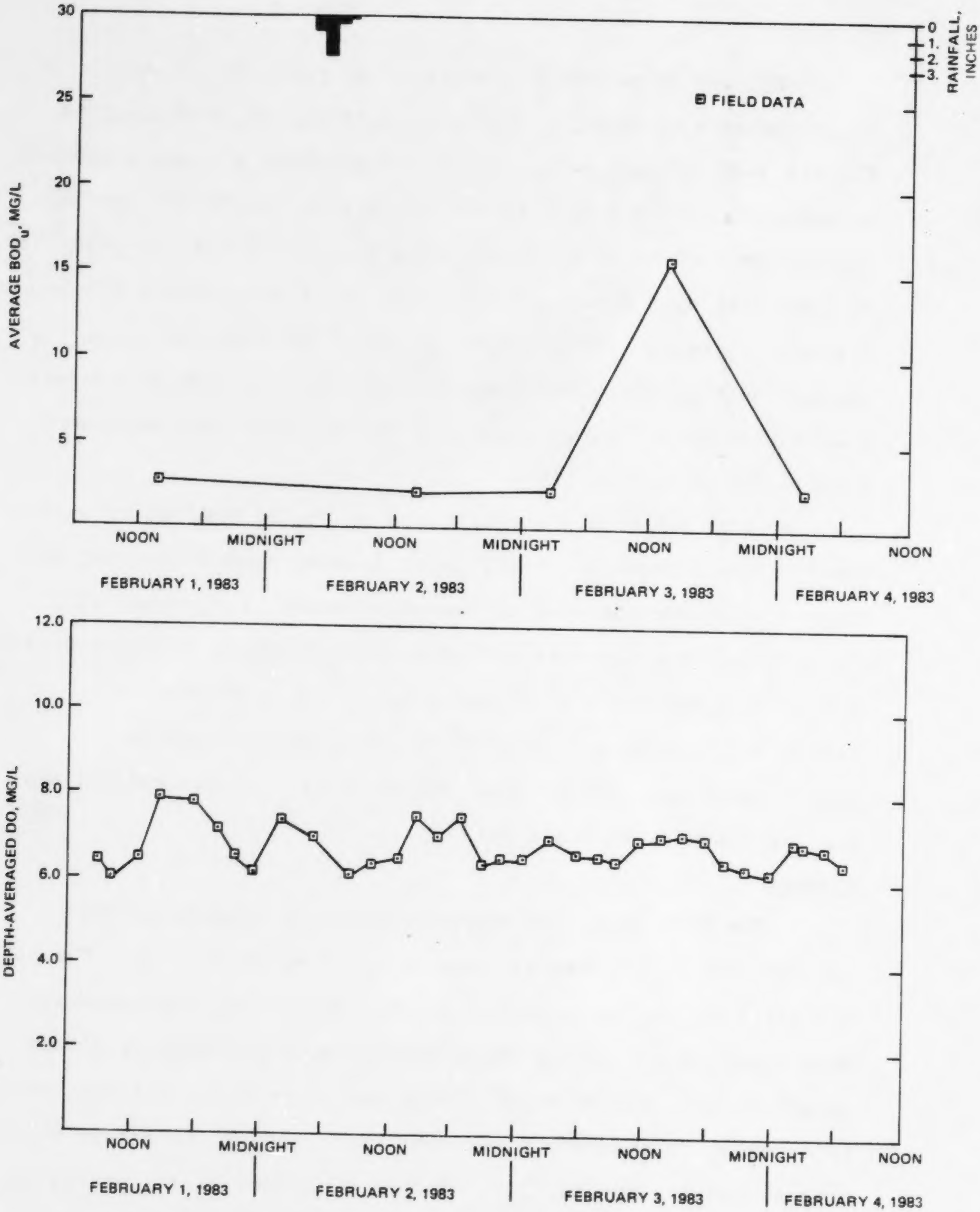


FIG. 4-27 TIME-VARYING BOUNDARY CONDITIONS FOR BOD$_u$ AND DO AT PLATT STREET SECOND VERIFICATION

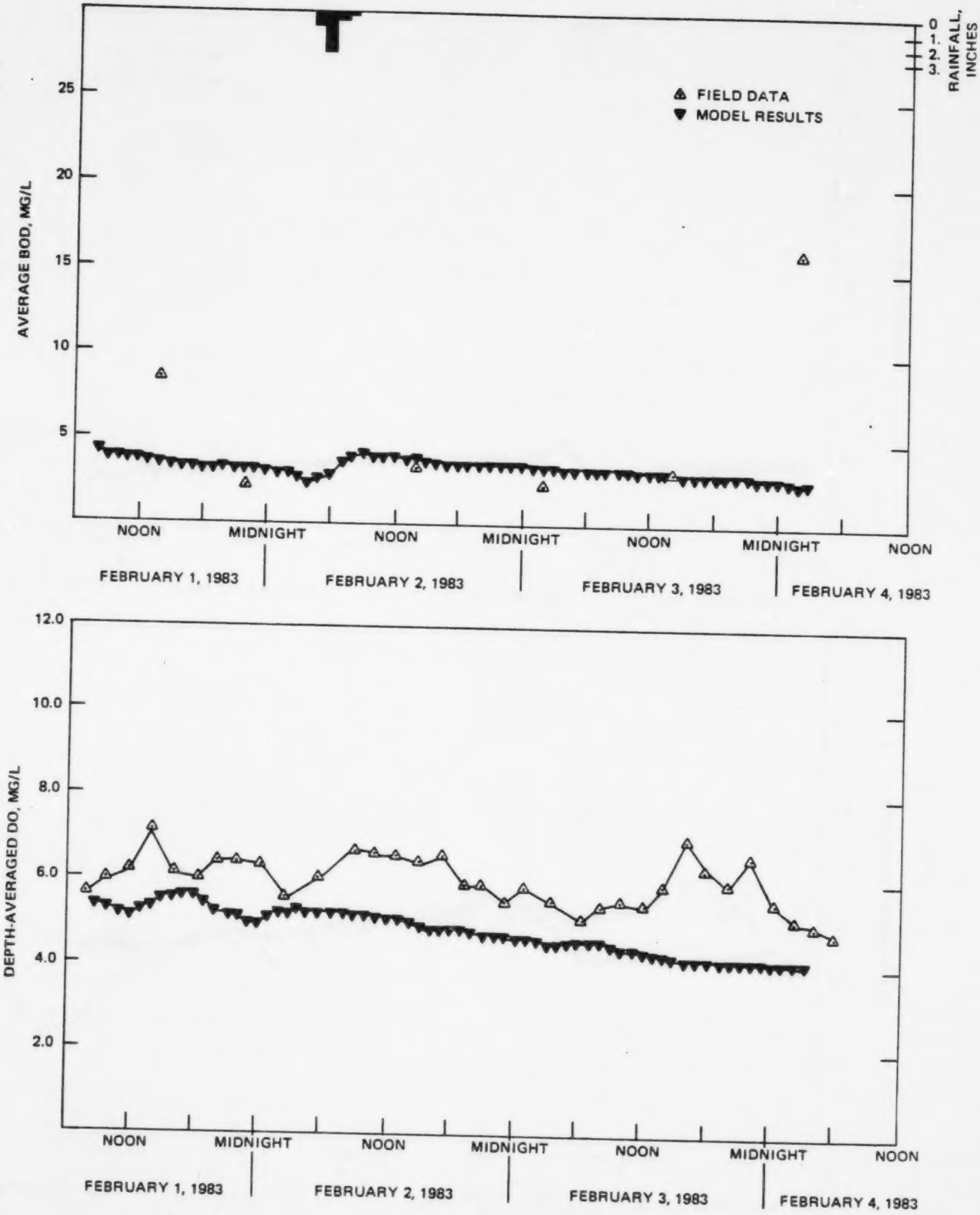


FIG. 4-28 BOD AND DO CONCENTRATIONS AT COLUMBUS DRIVE
SECOND VERIFICATION

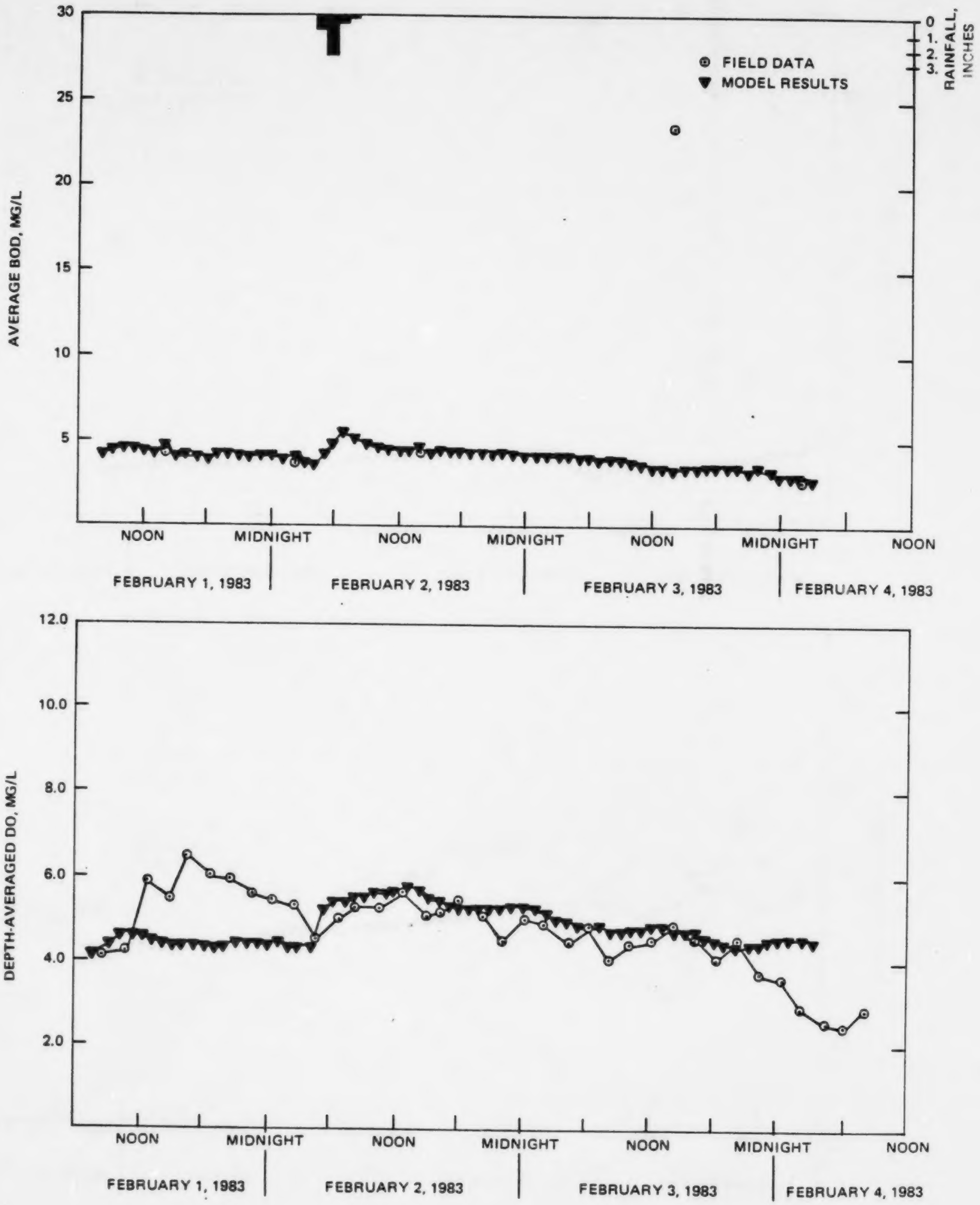


FIG. 4-29 BOD AND DO CONCENTRATIONS AT SLIGH AVENUE
SECOND VERIFICATION

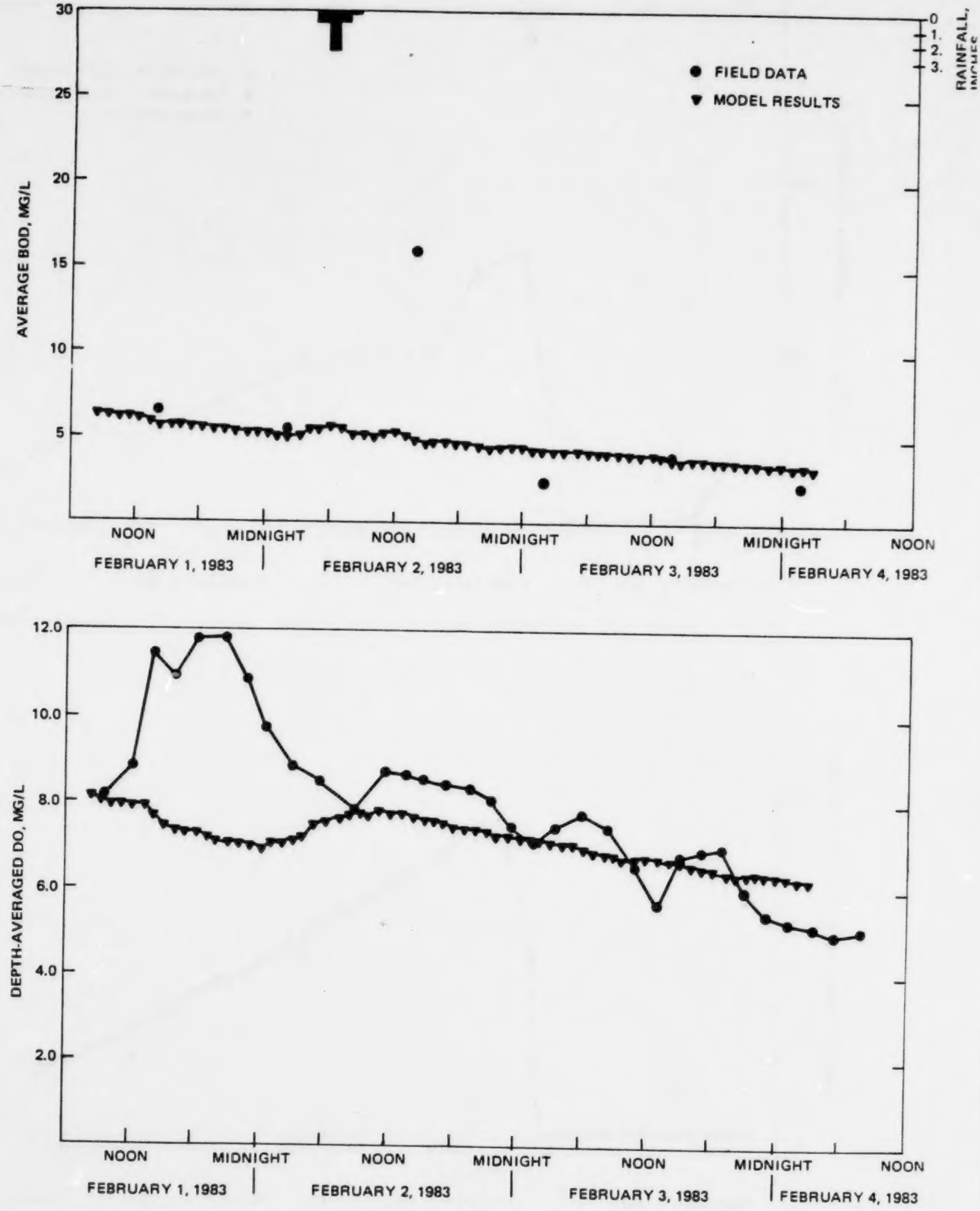


FIG. 4-30 BOD AND DO CONCENTRATIONS AT 22nd STREET - SECOND VERIFICATION

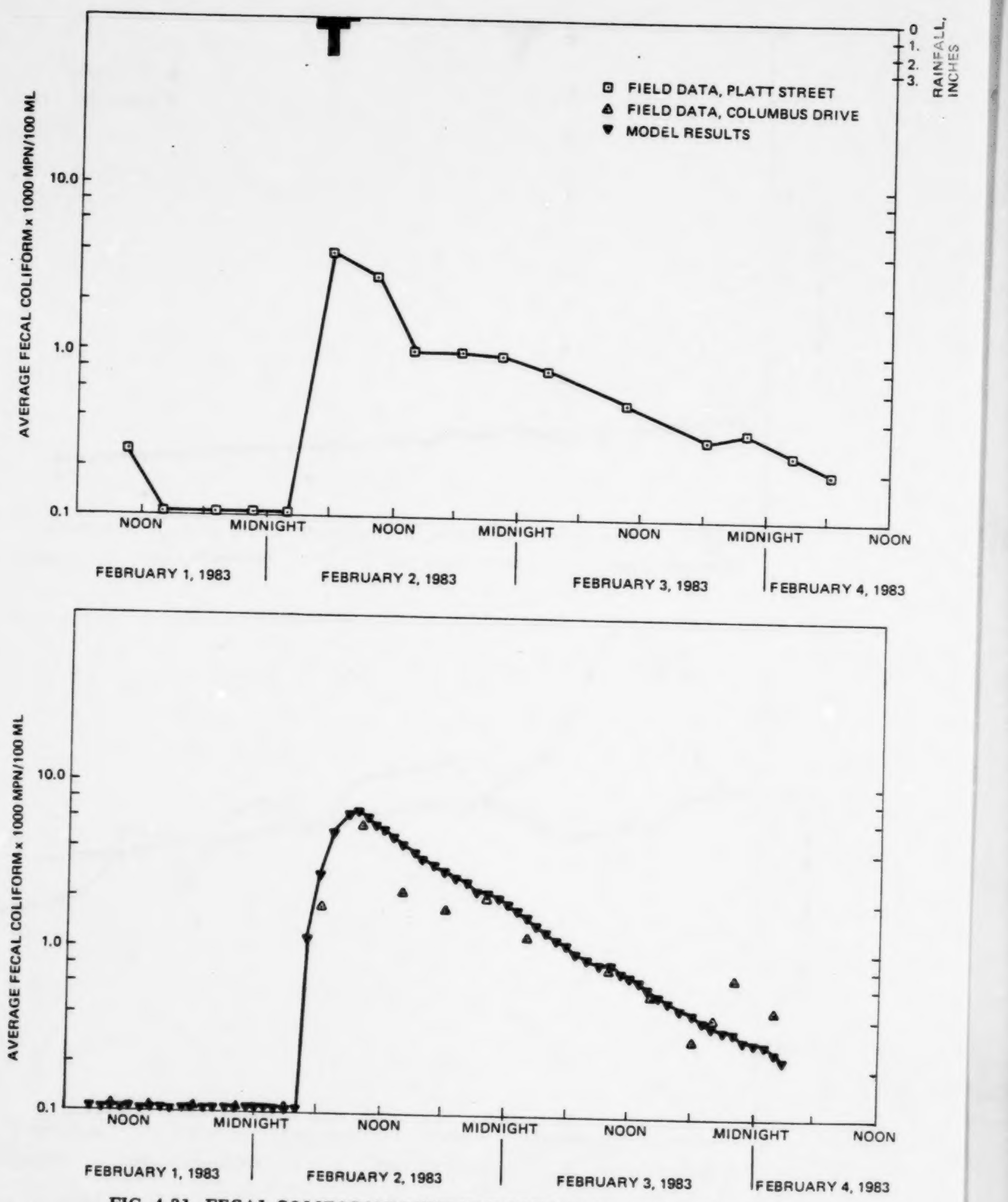


FIG. 4-31 FECAL COLIFORM BOUNDARY CONDITION AT PLATT STREET AND CALIBRATION RESULTS AT COLUMBUS DRIVE

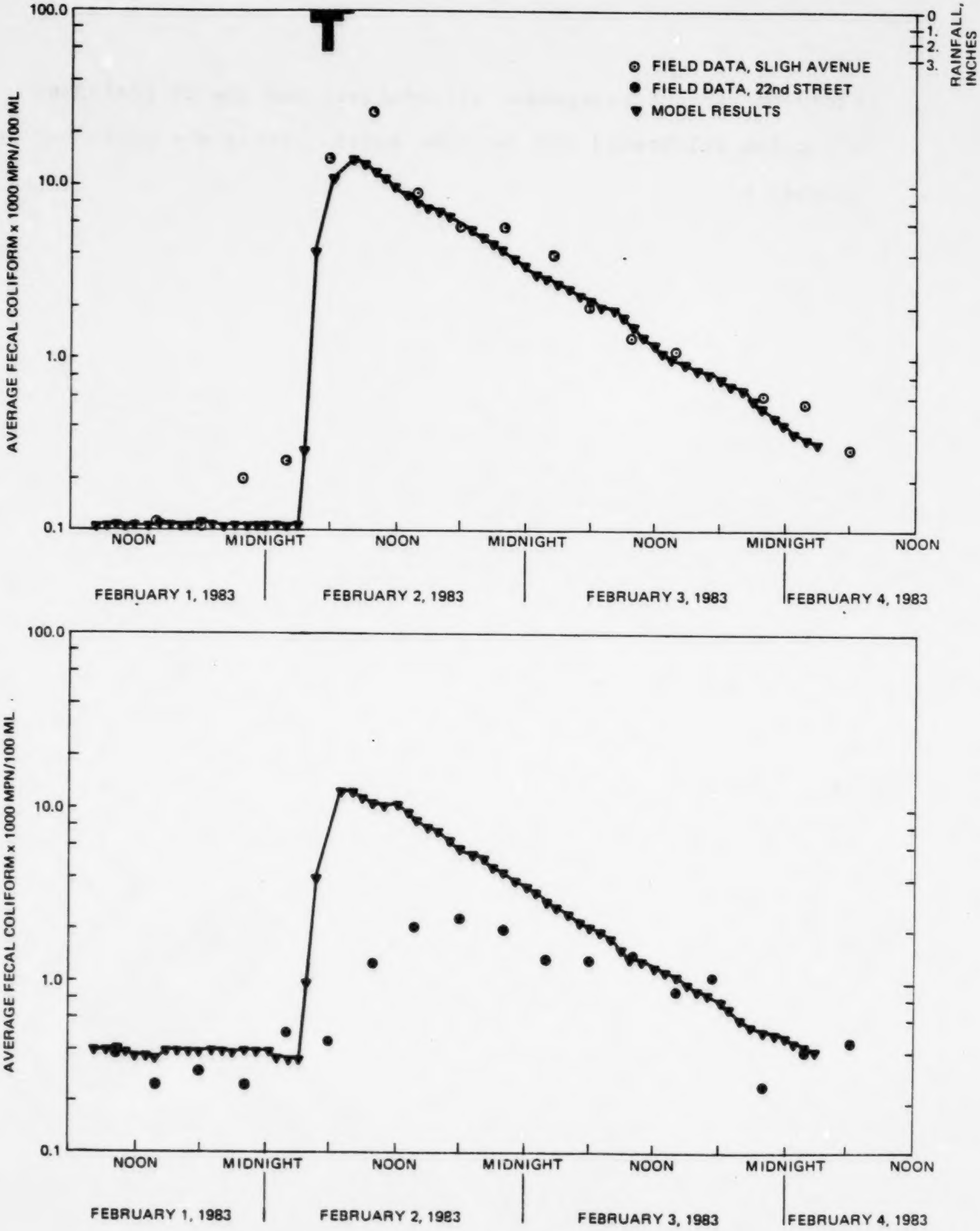


FIG. 4-32 FECAL COLIFORM CALIBRATION RESULTS
AT SLIGH AVENUE AND 22nd STREET

based on various management alternatives can now be performed using the calibrated and verified model. These are presented in Chapter 6.

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CHAPTER 5

VERTICAL VARIATIONS

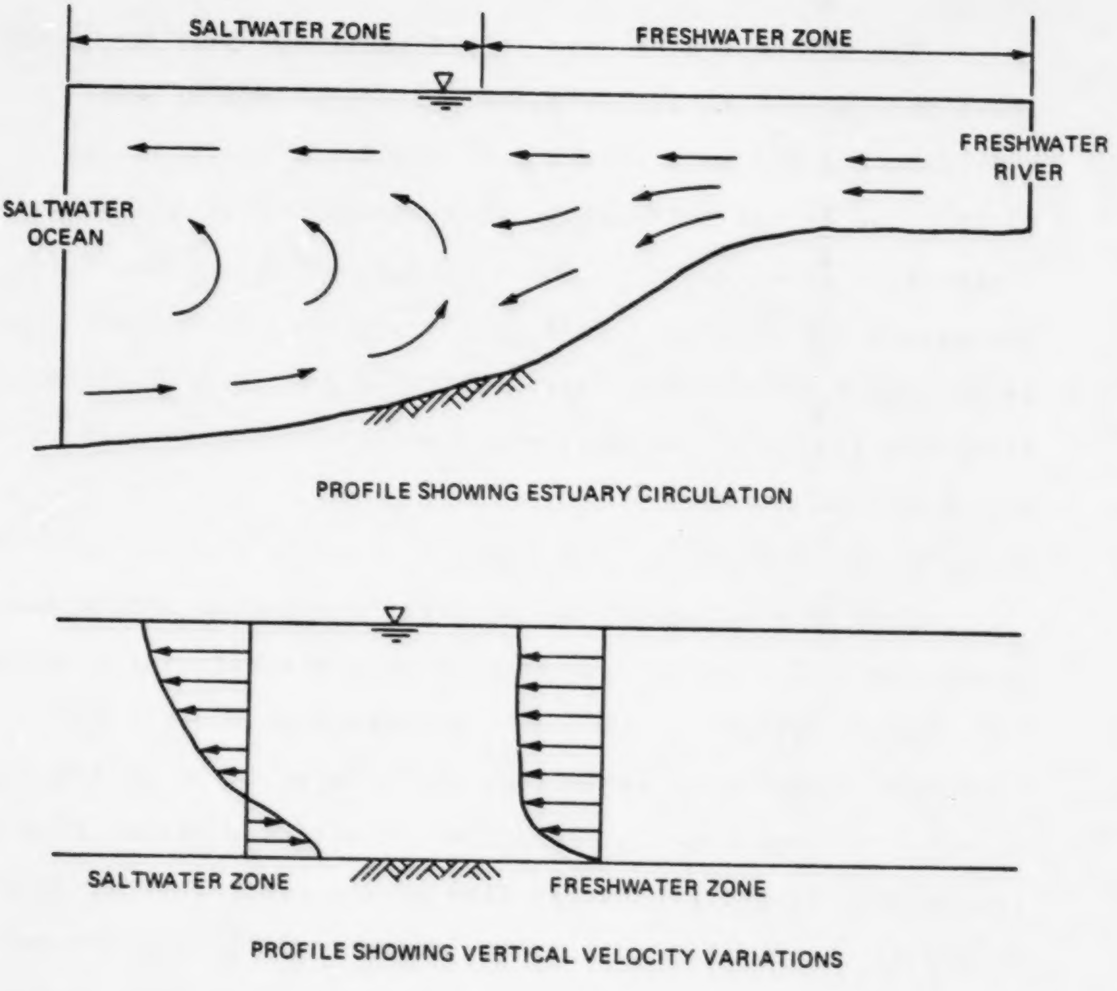
General

The discussion of data and modeling analysis up to this point has focused on the longitudinal variations of the hydrodynamics and water quality in the lower Hillsborough River. Due to the interaction of freshwater flow and salinity in a partially mixed estuary, the vertical variations in these parameters may also be significant. The purpose of this Chapter is to assess the vertical variability in the lower Hillsborough River and its impact on future projections using results of the one-dimensional model.

Vertical Variability in Estuaries

The interaction of the upstream freshwater inflow and downstream tidal variations results in a characteristic estuarine circulation pattern in the lower Hillsborough River. The influence of salinity variations on circulation in an estuary is depicted in Figure 5-1. Variations in salinity result from the interaction of the freshwater flow at the upstream end, tidal forces at the downstream end, and density difference between the fresh and salt water. The bottom waters tend to flow inward and the top waters tend to flow outward. This is also shown in Figure 5-1 by vertical variations of velocity.

The vertical variations in velocity and salinity (density) also affect the distribution of water quality parameters in the



SALTWATER ZONE
FRESHWATER ZONE
FRESHWATER RIVER
SALTWATER OCEAN
PROFILE SHOWING ESTUARY CIRCULATION
SALTWATER ZONE
FRESHWATER ZONE
PROFILE SHOWING VERTICAL VELOCITY VARIATIONS

FIG. 5-1 CIRCULATION PATTERNS AND VERTICAL VELOCITY VARIATIONS IN AN ESTUARY

water column. The quality of the saline waters intruding upstream in the bottom waters is often different from the freshwater which tends to remain in the upper part of the water column. Other impacts which result in vertical variations of water quality are tidal mixing energy, sediment oxygen demand and sediment resuspension and surface reaeration.

Vertical Variations in Field Data

The synoptic surveys discussed in Chapter 2 are analyzed further to evaluate the vertical variability of hydrodynamics and water quality in the lower River.

Vertical Velocity Variations. In Figure 5-2, tide and velocity (surface, mid-depth and bottom) at Platt Street during the February, 1983 synoptic survey are shown. During this survey, a large rainstorm occurred at about 4:00 AM on February 2. Before this storm, there was no freshwater flow entering from the Reservoir. The input of flow results in the characteristic estuarine circulation pattern. The surface velocities move mainly downstream, the bottom velocities move upstream, and the mid-depth velocities are in between. This verifies that the saline intrusion zone velocity pattern shown in Figure 5-1 does exist in the lower River. In sections where there is no salinity intrusion, there is little vertical variation of the velocity.

Figure 5-3 shows the vertical velocity profiles as measured during the February synoptic survey. The maximum vertical variation in velocity occurs at mid-ebb and low tides. This is the time when the downstream surface velocity is highest.

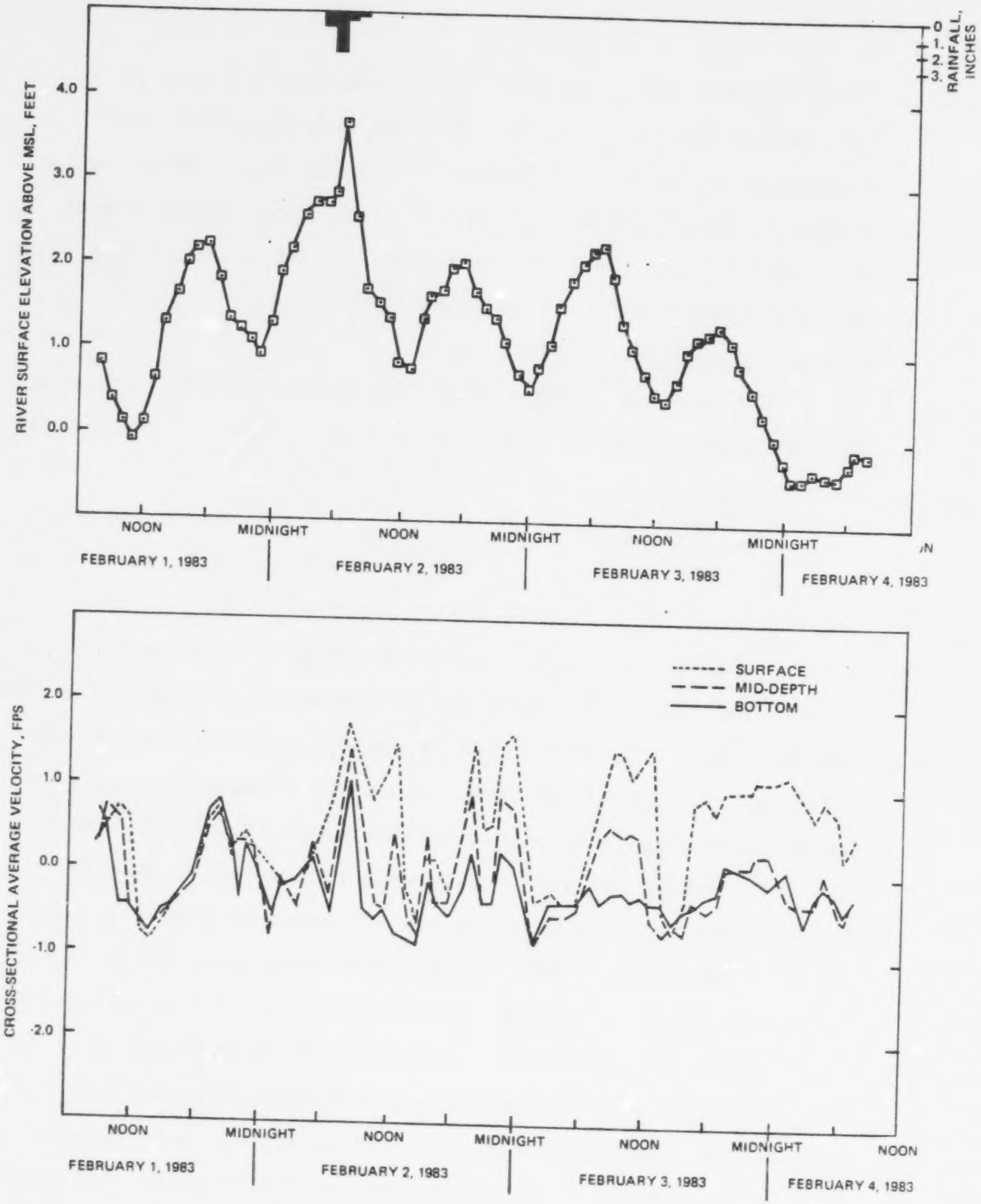
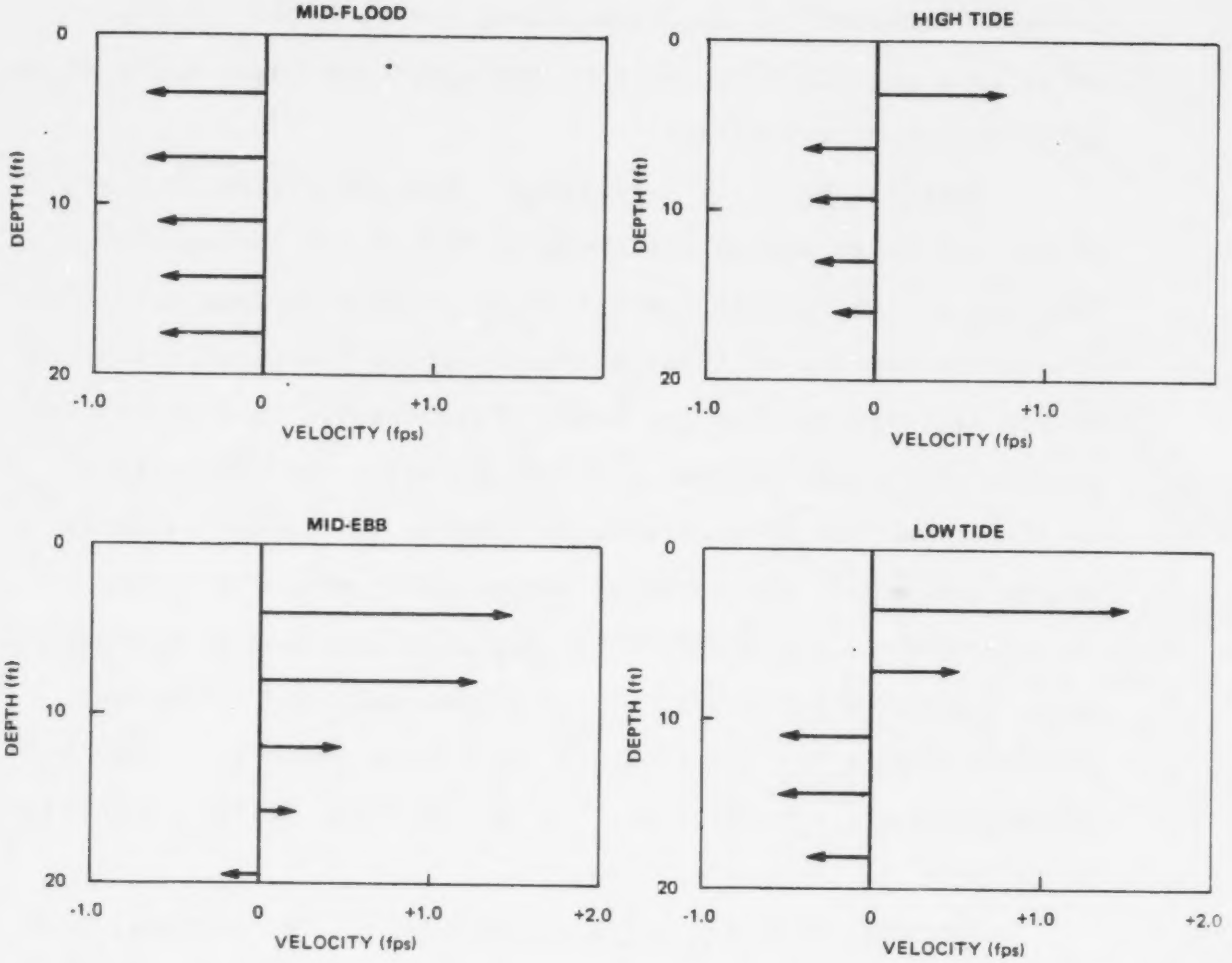


FIG. 5-2 TIDAL ELEVATION AND CURRENT VELOCITY AT PLATT STREET FEBRUARY, 1983



NOTE: NEGATIVE VELOCITY INDICATES UPSTREAM FLOW
POSITIVE VELOCITY INDICATES DOWNSTREAM FLOW

FIG. 5-3 VERTICAL VELOCITY PROFILES AT PLATT STREET
FEBRUARY 3, 1983

The bottom velocity, however, must still move upstream to preserve continuity. On flood tides, the vertical velocity variations are minimized as both the upper and lower parts of the water column move upstream.

Vertical Salinity Variations. The salinities at Platt Street and Sligh Avenue are shown in Figure 5-4 during the February survey. After the influx of freshwater from the storm event, the surface salinity at Platt Street decreases while the bottom salinity remains the same. This results in a significant density difference in the water column which did not exist prior to the storm. At Sligh Avenue salinities in the entire water column decrease. The vertical variation in salinity first decreases after the event, then begins to increase as the saline wedge begins to stabilize. The vertical salinity variations shown in Figure 5-4 and velocity variations shown in Figure 5-2 demonstrate the expected response of the lower Hillsborough River to an input of freshwater flow.

Vertical Dissolved Oxygen Variations. The surface, mid-depth, and bottom DO concentrations at Platt Street and Sligh Avenue are shown in Figure 5-5. It is interesting to note that the vertical variation in DO is greatest when there is a significant vertical salinity variation. The salinity (and thus density) variations inhibit mixing of the water column. Reaeration tends to be limited to the upper part of the water column, while sediment oxygen demand is limited to the lower

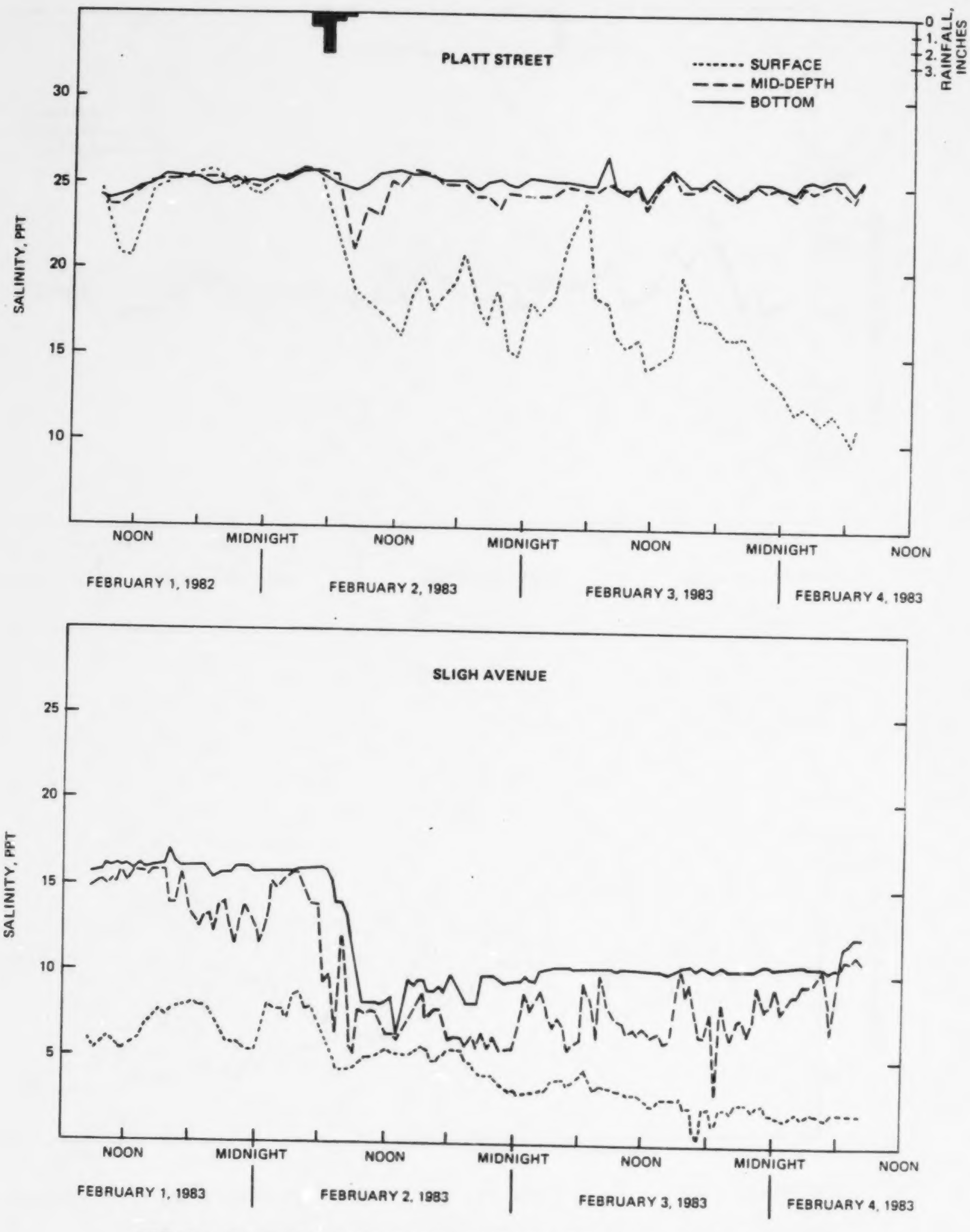


FIG. 5-4 SALINITY VARIATION AT PLATT STREET AND SLIGH AVENUE
FEBRUARY, 1983

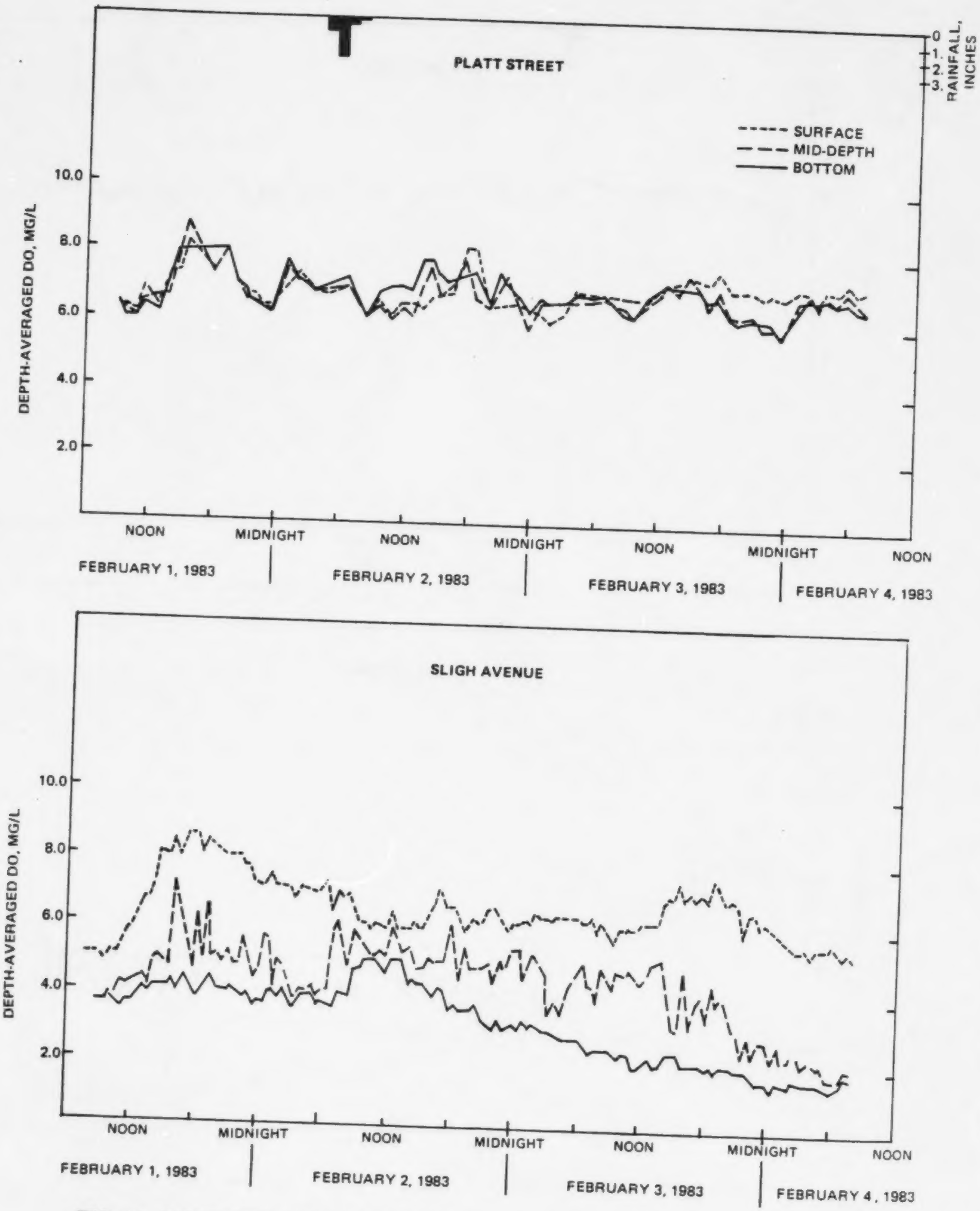


FIG. 5-5 DISSOLVED OXYGEN VARIATION AT PLATT STREET AND SLIGH AVENUE FEBRUARY, 1983

part. These two effects are in part responsible for the large vertical DO gradients.

Vertical Variations of Suspended Solids. Because of the large expense of field measurement programs, detailed vertical profiles of all water quality data could not be obtained. Because of suspected impact of stormwater on solids and coliform bacteria concentrations in the Lower Hillsborough River, surface and bottom samples of these parameters were obtained during the field surveys.

The surface and bottom concentrations of TSS at Platt Street and Sligh Avenue during the Febraury, 1983 survey are shown in Figure 5-6. In general, the bottom TSS concentrations are somewhat higher than surface concentrations. This is expected to occur, since the bottom velocities bring in solids from the Bay into the Hillsborough River. Also, the increase of TSS concentrations after the storm event can be clearly identified.

Vertical Variations of Coliform Bacteria. Total coliform bacteria concentrations, as shown in Figure 5-7, are generally higher in the upper part of the water column. This would be expected because surface water, which is mainly composed of stormwater, enters the Hillsborough River after a storm and tends to move above the bottom, more saline water. In addition, bacteria are known to die-off more rapidly in saline water. Also, the storm event is responsible for large increases in coliform bacteria concentration in the lower River.

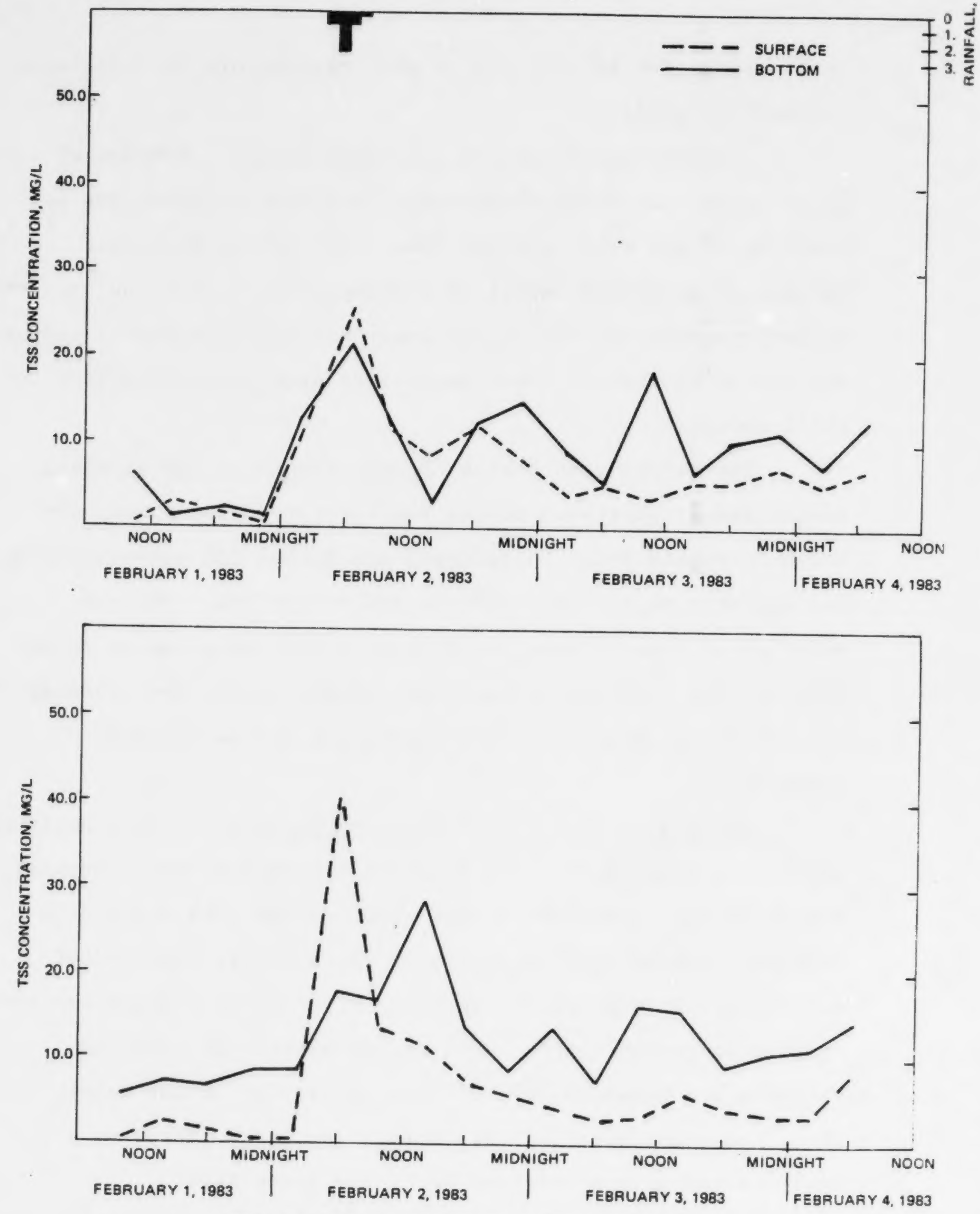


FIG. 5-6 TOTAL SUSPENDED SOLIDS VARIATION
AT PLATT STREET AND SLIGH AVENUE - FEBRUARY, 1983

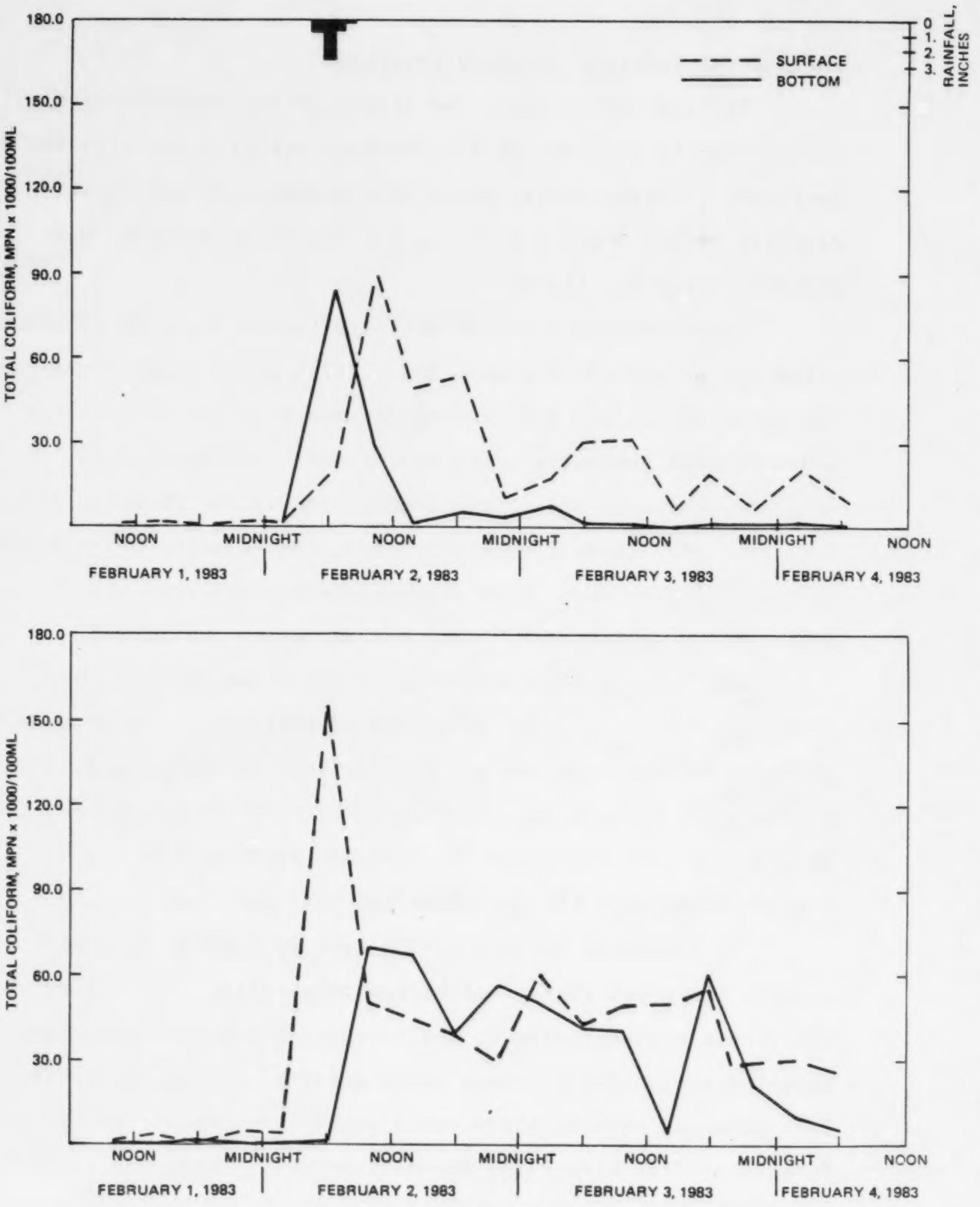


FIG. 5-7 TOTAL COLIFORM VARIATION AT PLATT STREET AND SLIGH AVENUE - FEBRUARY, 1983

Analysis of Vertical Salinity Profiles

To take into account the effect of the observed vertical variations, an analysis of the vertical salinity profiles was performed. Dimensionless plots were prepared at each station for salinity versus depth. Plots were prepared at mid-ebb, high, mid-flood, and low tides.

Dimensionless plots of salinity versus depth at Columbus Drive are presented in Figure 5-8. These plots clearly portray the variation in salinity concentrations over the tidal cycle under various freshwater flow conditions. Strong vertical salinity gradients are observed most clearly for flows of 270 and 1000 cfs. For lower freshwater flows, the Columbus Drive station is nearly all saline. Such dimensionless plots were also prepared for 22nd Street, Sligh Avenue, and Platt Street.

The dimensionless plots of salinity can be used to directly predict vertical variation of salinity at Columbus Drive or the other stations for any freshwater flow conditions. The procedure is to take the cross-sectional average value predicted by WQON and back-calculate the vertical profile from the dimensionless plot for the specified flow and tidal period.

It should be noted that the same freshwater flow may produce different degrees of saline penetration. In Figure 5-8 the curves corresponding to the February survey reflect higher salinity concentrations than those obtained in the May survey. This occurred because there was a longer antecedent time of no freshwater flow before the February survey. Thus, the transition

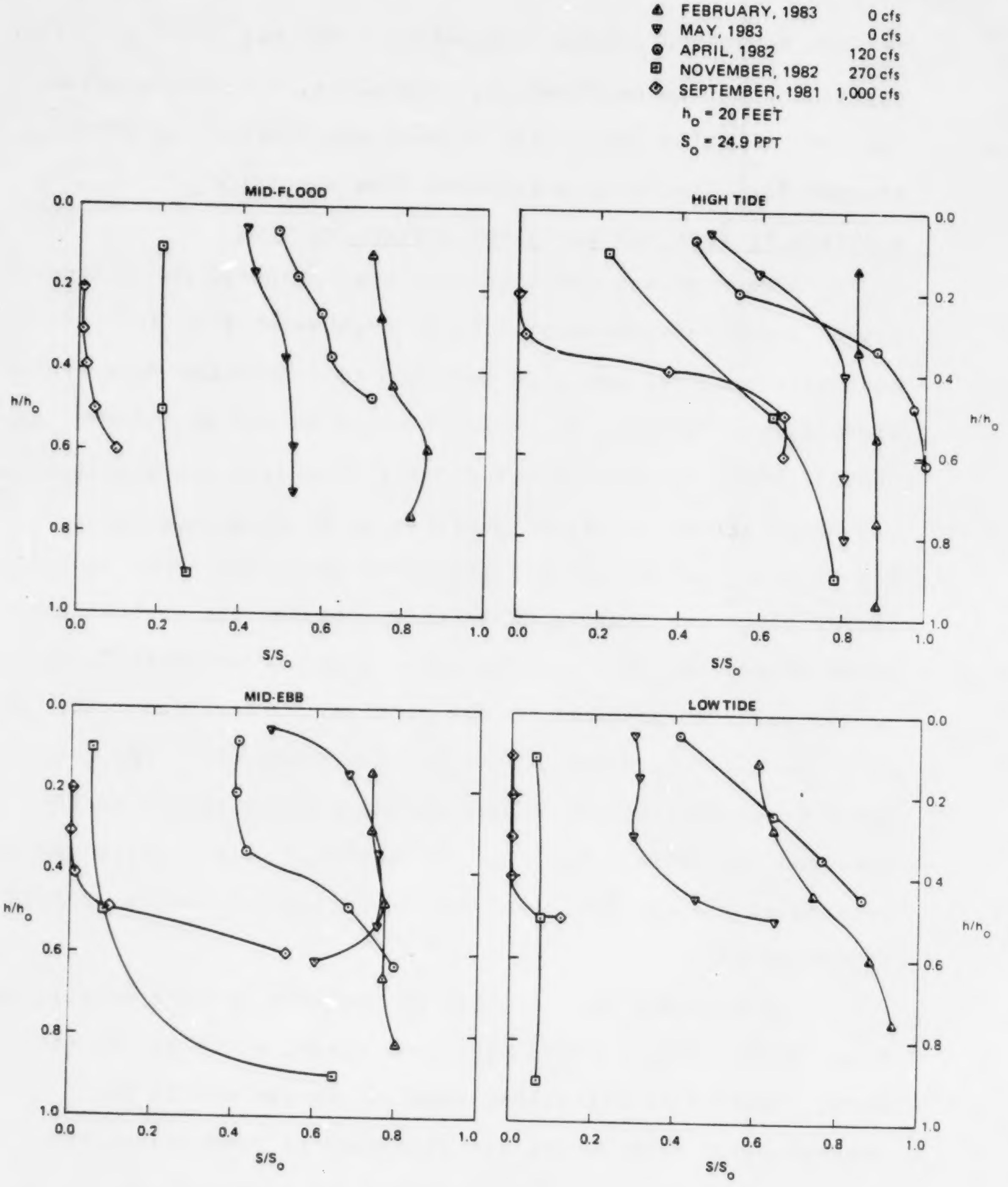


FIG. 5-8 DIMENSIONLESS SALINITY PROFILES AT COLUMBUS DRIVE FOR VARIOUS FRESHWATER FLOW CONDITIONS

periods between different freshwater flows may cause different degrees of saline penetration. Therefore, the dimensionless vertical salinity plots must be used and interpreted properly to account for effects of antecedent flow conditions.

Analysis of Vertical Dissolved Oxygen Profiles

Dimensionless profiles were also prepared for dissolved oxygen under varying conditions of freshwater flow and tide. It must be remembered that, in addition to freshwater flow and tidal circulation, vertical DO variations are caused by sediment oxygen demand (SOD), reaeration, vertical diffusivity and photosynthesis and respiration. Vertical profiles at Sligh Avenue, shown in Figure 5-9, indicate that significant gradients exist when the saline wedge has penetrated to this location due to low freshwater flows. At this station under higher freshwater flows there is virtually no gradient in the vertical DO profiles. The lowest DO's occur during flows of 0, 100, and 1,000 cfs. The quality of water entering from the Reservoir has a major impact on the observed concentrations. The variation of this quality may be related to whether the water released from the Dam is surface or bottom water.

To evaluate the vertical DO profiles in more detail, the model SSDOP (Steady State Dissolved Oxygen Profile) (1) was used. This model calculates vertical variations in DO concentration considering the influence of reaeration, SOD, vertical diffusivity, photosynthesis and respiration. It is based on the steady-state one-dimensional (vertical) conservation of mass equation neglecting advection.

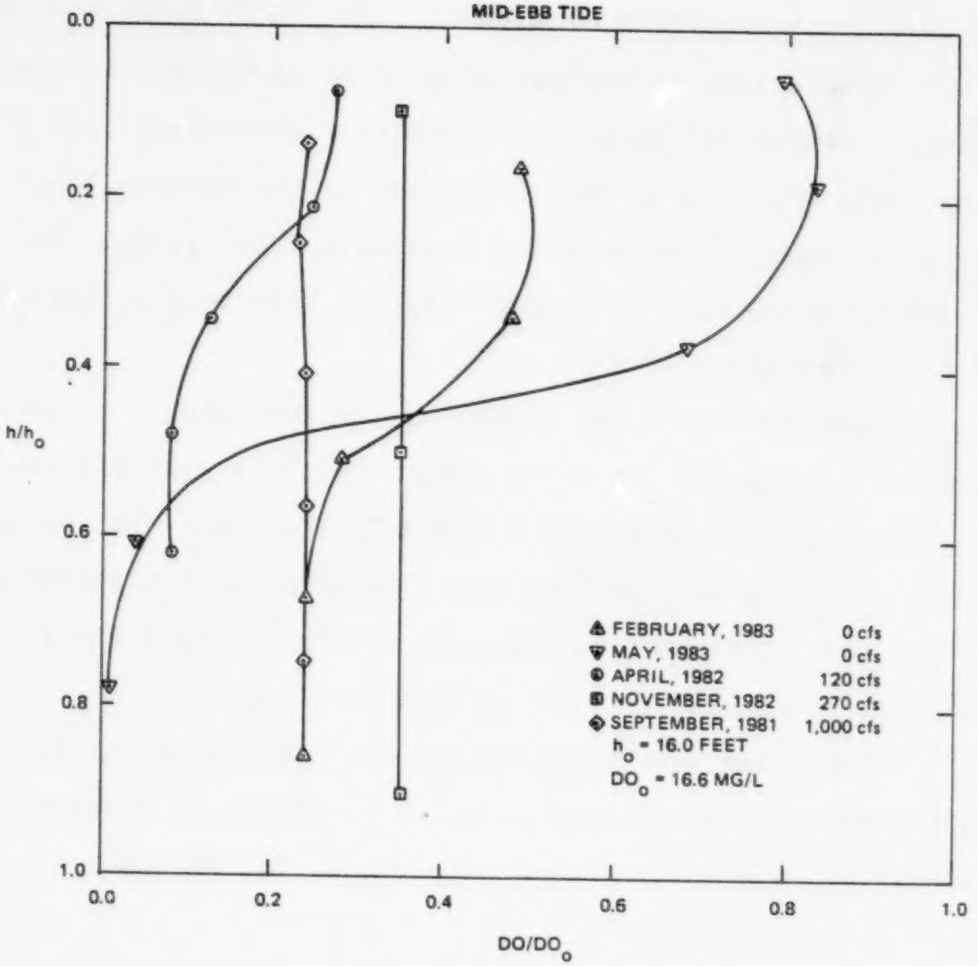


FIG. 5-9 DIMENSIONLESS DO PROFILES AT SLIGH AVENUE FOR VARIOUS FRESHWATER FLOW CONDITIONS

In order to demonstrate the use of SSDOP, vertical diffusivities were first calculated for several points in the tidal cycle during the synoptic surveys using measured vertical density gradients from the synoptic survey data. The range of diffusivities over a tidal cycle is presented in Table 5-1 for various freshwater flow conditions. The SSDOP model accounts for a two-layer system to reflect stratified conditions in the water column. Higher diffusivities indicate a well-mixed layer. In many cases there is no stratification at the various stations which reflects either dominant freshwater flow (e.g., 22nd Street at 100 or 1,000 cfs) or dominant saline flow (e.g., Platt Street at zero freshwater flow).

Photosynthesis and algal respiration rates are also necessary inputs to the SSDOP model. No data were available on photosynthesis or respiration rates in the lower Hillsborough River. A study of phytoplankton production in Hillsborough Bay by the City of Tampa Department of Sanitary Sewers (2) produced a photosynthesis rate of 0.65 to 25.8 mg/l/day.

SOD rates were based on the field measurements conducted during dry and wet weather flows as discussed in Chapter 4. The reaeration rate was based on values used for WQON model calibration in Chapter 4.

The SSDOP Model was applied to the February survey. The model inputs are shown in Table 5-2. Figures 5-10 through 5-13 present the field data and model results at all four stations at mid-flood, high tide, mid-ebb and low tide. The field data

TABLE 5-1. VERTICAL DIFFUSIVITY COEFFICIENTS FOR VARIOUS FRESHWATER FLOW CONDITIONS

Freshwater Flow (cfs)	Water Column Layer	Range of Vertical Diffusivity (cm^2/s)			
		Platt Street	Columbus Drive	Sligh Avenue	22nd Street
0	upper	4.0-40.0	0.1-4.0	0.04-0.30	0.03-4.0
	lower	4.0-40.0	0.1-4.0	0.40-10.0	0.03-4.0
100	upper	0.03-2.0	0.03-2.2	0.03-4.0	20-100
	lower	0.03-30.0	0.03-0.45	0.03-8.0	20-100
1000	upper	0.03-20.0	0.2-40.0	20-100	20-100
	lower	0.03-20.0	0.03-0.3	20-100	20-100

TABLE 5-2. SSDOP MODEL INPUTS FOR FEBRUARY VERTICAL DO SIMULATION

Station and Tide	Vertical Diffusivity(cm^2/s) upper layer	Vertical Diffusivity(cm^2/s) lower layer	Photosynthesis mg/l/day	Respiration(mg/l/d) upper layer	Respiration(mg/l/d) lower layer	DO Transfer m/day	SOD $g/m^2/d$	DO saturation(mg/l) upper layer	DO saturation(mg/l) lower layer
Platt St.									
Mid-Flood	10	10	3.45	0	0	0.5	9.8	6.8	6.8
High Tide	20	20	2.07	0	0	0.5	9.8	6.8	6.8
Mid-Ebb	10	10	1.83	0	0	0.5	9.8	6.8	6.8
Low Tide	20	20	2.88	0	0	0.5	9.8	6.8	6.8
Columbus Dr.									
Mid-Flood	0.6	0.6	2.30	0	0	0.5	6.1	7.0	6.8
High Tide	8.0	8.0	1.85	0	0	0.5	6.1	7.0	6.8
Mid-Ebb	4.0	4.0	1.97	0	0	0.5	6.1	7.0	6.8
Low Tide	0.6	0.1	0.90	0	0	0.5	2.1	7.0	6.8
Sligh Ave									
Mid-Flood	0.06	8.0	1.25	0	0	0.5	2.6	8.2	7.6
High Tide	0.09	10.0	1.04	0	0	0.5	2.6	8.2	7.6
Mid-Ebb	0.09	8.0	1.2	0	0	0.5	2.6	8.2	7.6
Low Tide	0.06	0.09	0.0	0	0	0.5	0.5	8.2	7.6
22nd St.									
Mid-Flood	0.8	0.8	2.70	0	0	0.5	4.1	8.2	8.2
High Tide	0.6	0.6	7.00	0	0	0.5	4.1	8.2	8.2
Mid-Ebb	1.0	1.0	4.80	0	0	0.5	4.1	8.2	8.2
Low Tide	0.1	0.1	1.00	0	0	0.5	1.1	8.2	8.2

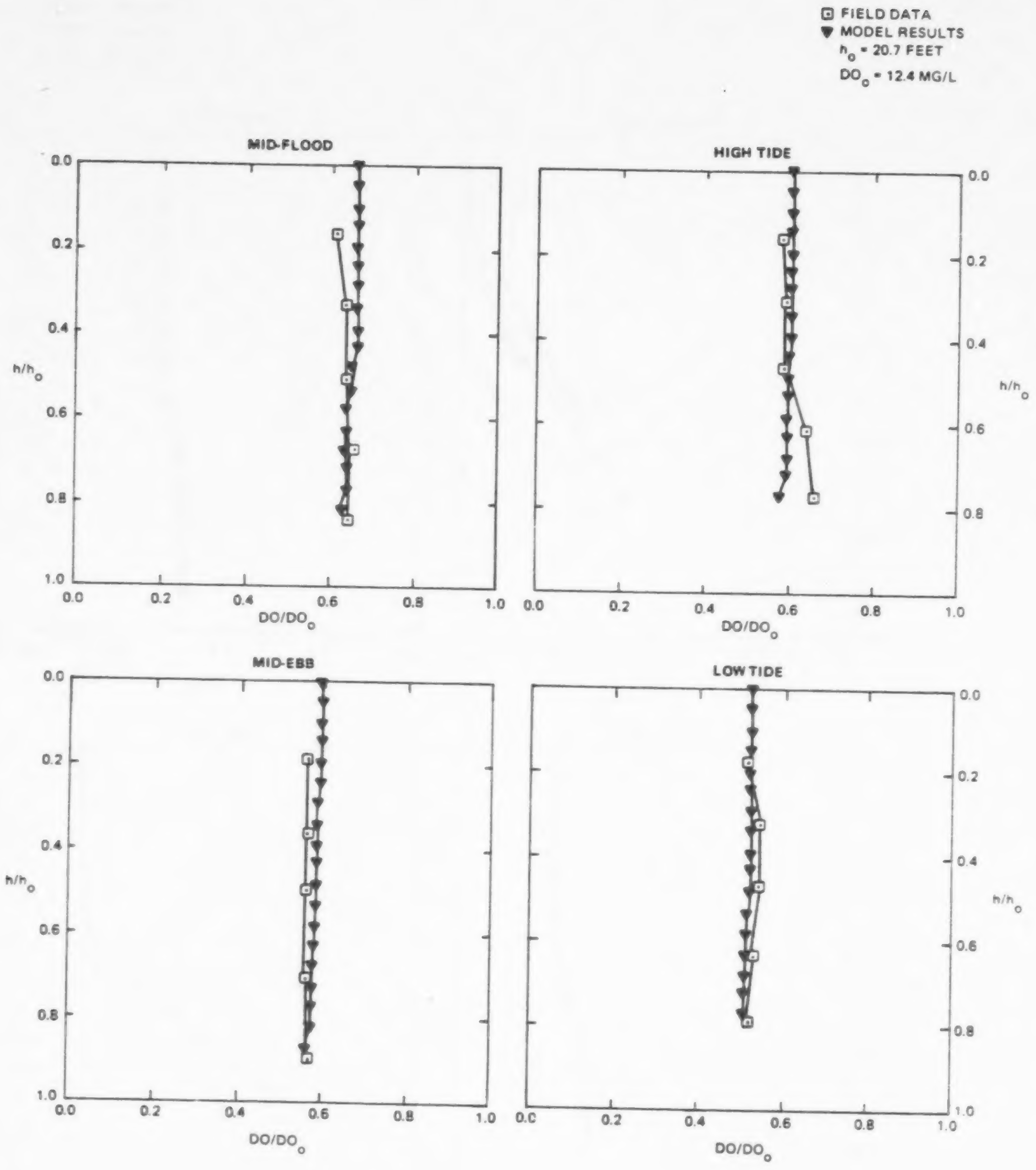


FIG. 5-10 SSDOP MODEL RESULTS AT PLATT STREET
FEBRUARY, 1983

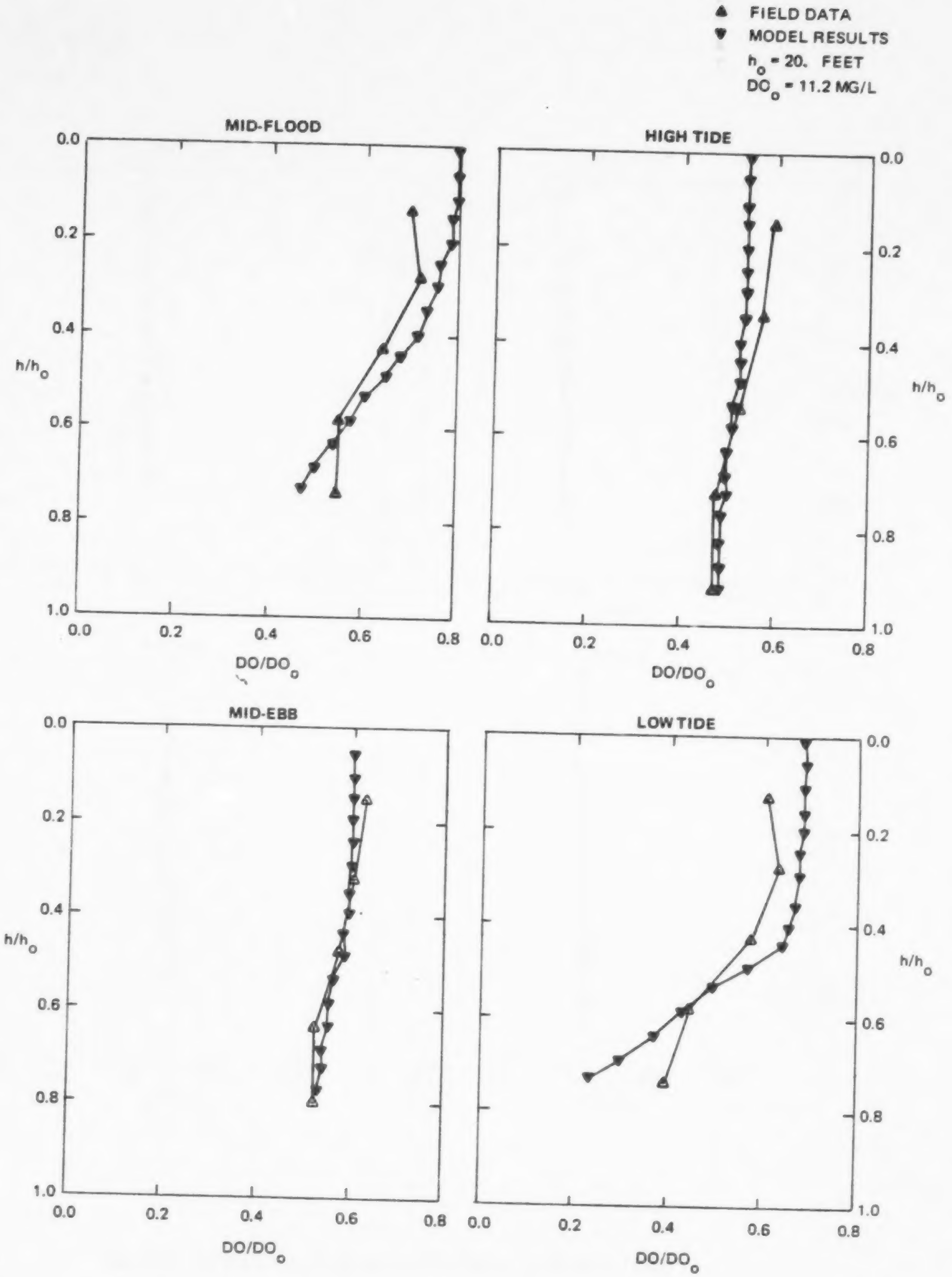


FIG. 5-11 SSDOP MODEL RESULTS AT COLUMBUS DRIVE - FEBRUARY, 1983

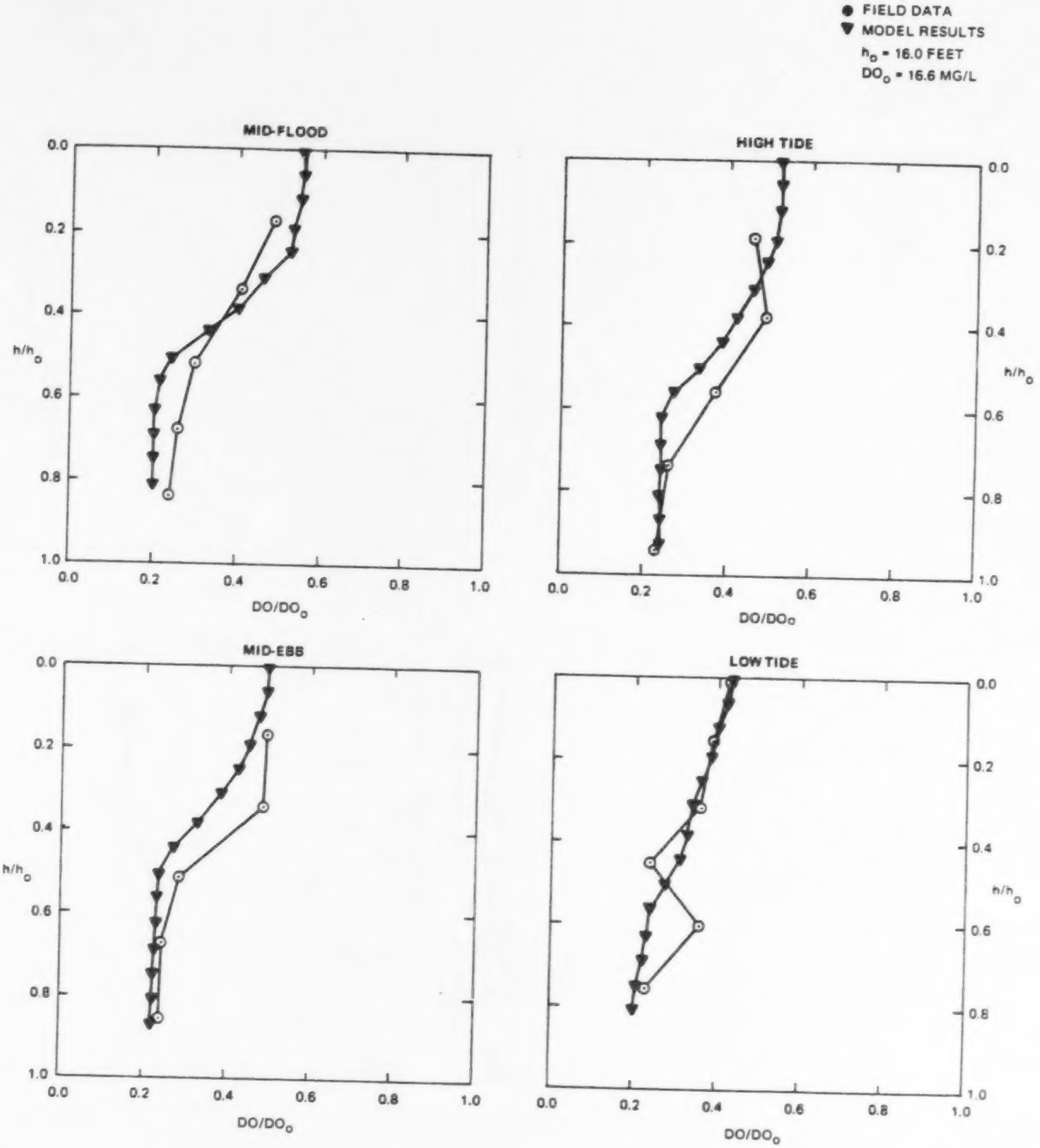


FIG. 5-12 SSDOP MODEL RESULTS AT SLIGH AVENUE
FEBRUARY, 1983

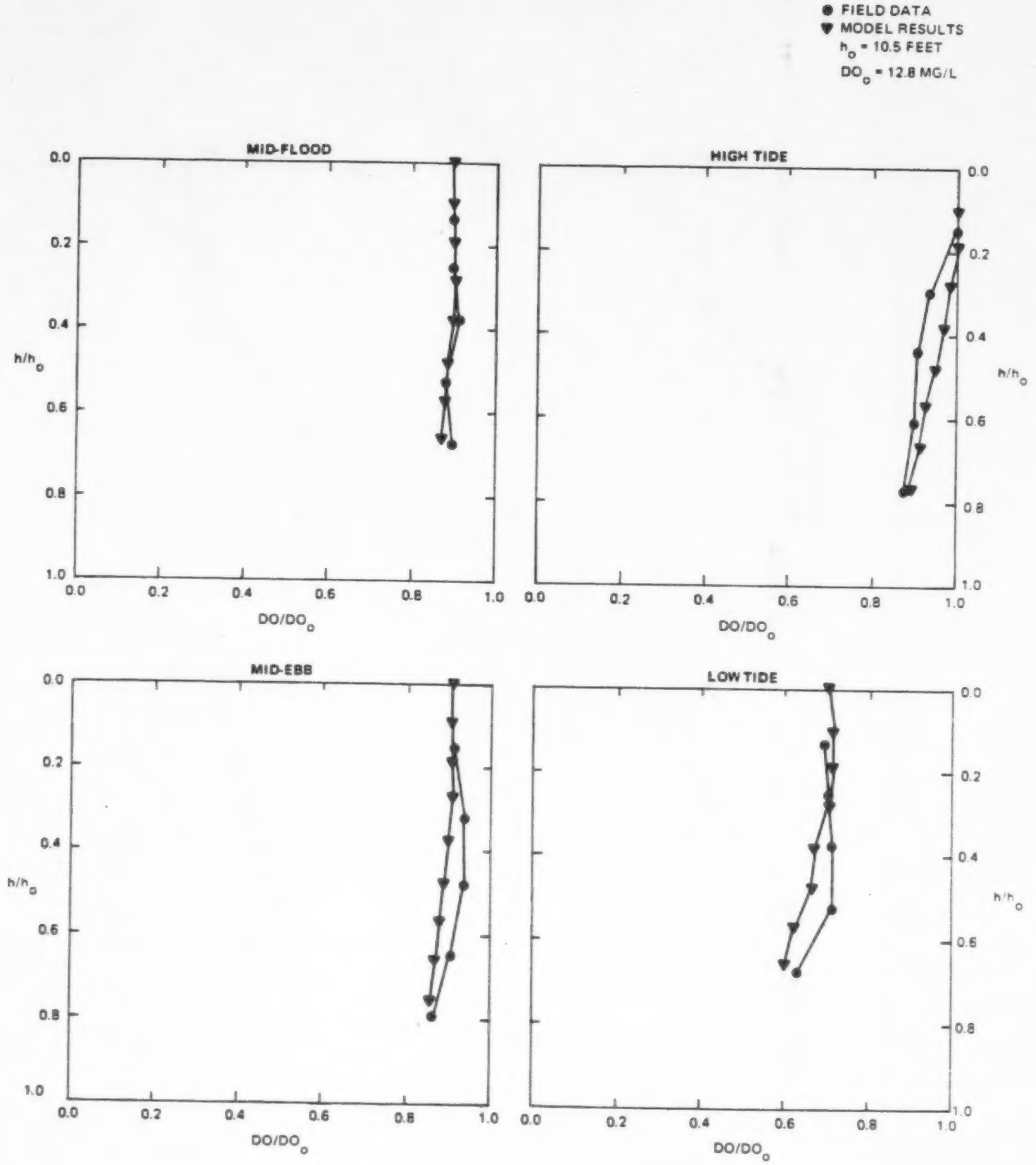


FIG. 5-13 SSDOP MODEL RESULTS AT 22nd STREET
FEBRUARY, 1983

indicated that some algal activity was present at all stations during this survey. The rate of photosynthesis was therefore adjusted until a good fit was observed between SSDOP results and field data.

Summary

Vertical variations of salinity and dissolved oxygen in the lower Hillsborough River have been analyzed in detail for various freshwater flow and tidal conditions. Variations of dissolved oxygen in the water column are primarily a result of stratification due to saline penetration in the River. However additional factors such as algal production and respiration, surface reaeration, sediment oxygen demand and the relative depths of the freshwater and saltwater layers all contribute to the DO variation in the River. In well-mixed saline or freshwater regions the DO levels are relatively constant from surface to bottom.

A method to obtain vertical salinity and DO profiles from the one-dimensional WQON model output has been implemented. This method applies to segments of the River that are vertically stratified. The WQON results can be assumed to represent DO concentrations for the entire water column for segments of the River that are not stratified.

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2. City of Tampa, Department of Sanitary Sewers, The Effects of Sewage Pollution Abatement on Phytoplankton Productivity and Standing Crop in Hillsborough Bay, Florida, October, 1979.

CHAPTER 6

ASSESSMENT OF ALTERNATIVES

General

The analyses of data collected on the lower Hillsborough River have identified a number of factors that contribute to its poor water quality. Alternative water quality strategies are therefore developed and analyzed in this Chapter. Initially, each water quality parameter is reviewed to identify existing problems in the River. Estimates of pollutant loadings from various inflow sources are than made. Finally, several management alternatives to alleviate problems are evaluated to determine expected improvements in the water quality of the lower Hillsborough River.

Problem Identification

Table 6-1 presents the State of Florida Water Quality Criteria (Chapter 17-3) for Class III waters. The range of concentrations for several parameters as measured during the synoptic surveys is also presented. The parameters that violate State criteria are DO, fecal and total coliform and copper. The factors that cause these violations as well as characteristics of the constituents under various hydrologic and meteorologic conditions are presented in the following discussions.

Salinity. The concentration of salinity and the extent of saline penetration are dependent on freshwater discharges from Hillsborough Reservoir and Sulphur Springs. A long-term presence

TABLE 6-1. COMPARISON OF LOWER HILLSBOROUGH RIVER WATER QUALITY CRITERIA WITH RIVER DATA

Parameter	Unit	Criteria	River Data
BOD_5	mg/l	shall not cause DO depressions violating standards	1-16
DO	mg/l	never less than 4 mg/l	0.0-16
COD	mg/l	-	7-106
TSS	mg/l	settle to form putrescent deposits or a nuisance; produce a turbidity nuisance; < 29 NTU's above background; depth of compensation < 10% change	1-71
Ortho-P	mg/l	man-induced nutrient load shall not cause an imbalance in natural populations of aquatic flora and fauna	0.08-0.93
Total P	mg/l		0.15-0.95
Nitrate	mg/l		0.001-0.940
Nitrite	mg/l		0.000-0.022
TKN	mg/l		0.15-5.83
Ammonia-N	mg/l		0.044-0.770
Organic-N	mg/l		0.38-5.60
Total-N	mg/l		0.71-6.10
Fecal Coliform	$\frac{MPN}{100ml}$	monthly average < 200 daily average < 800	40-26,500
Total Coliform	$\frac{MPN}{100ml}$	monthly average < 1,000 never > 2,400	300-600,000
Aluminum	ug/l	1,500	50-530
Copper	ug/l	15	3-57
Lead	ug/l	50	4-26
Zinc(1)	ug/l	30	4-90

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1. Freshwater Criteria = 30; General Surface Water Criteria = 1,000.

of saline water due to low freshwater inflow tends to depress DO concentrations in the River. In addition, dissolved oxygen concentrations are lowest in the vicinity of the farthest upstream penetration of salt water. During periods of no freshwater flow the saline wedge penetrates up to 22nd Street and reduces DO levels in that vicinity. The downstream segments contain a significant salt water concentration and average DO levels in the lower Hillsborough River range from 2.8 to 4.1 mg/l (Chapter 2). Under such conditions stormwater runoff entering the River tends to improve DO concentrations as well as reduce saline levels in the upstream segements of the River.

Dissolved Oxygen and BOD. From the synoptic surveys and the continuous data analysis it appears that dissolved oxygen concentrations are affected primarily by salinity intrusion, freshwater discharges from the Hillsborough Reservoir and sediment oxygen demand. Dissolved oxygen concentrations in the River do not seem to be seriously affected by stormwater runoff. BOD concentrations in the River range from 1 to 4 mg/l and also do not appear to increase significantly after storm events.

A design storm was selected during the Phase III Study of NURP Project which would cause the greatest water quality impact on the River. The storm had a two hour duration and a one month return period with a total rainfall of 0.96 inches. A condition of zero freshwater flow from the upstream reservoir was selected for the River and the storm was routed through all drainage areas to develop inflows and loadings to the River. Initial dissolved oxygen concentrations and DO levels 18 hours after the storm are shown in Figure 6-1. The stormwater runoff was assumed to have a conservative DO concentration of 5.0 mg/l in this simulation. As a result of the stormwater runoff the DO levels improved in the vicinity of 20,000 feet below the Dam where initial DO concentrations were around 2 to 3 mg/l. Further upstream initial DO concentrations were 5 to 7 mg/l and decreased due to the stormwater BOD and DO levels. The impact of a storm on DO levels is therefore dependent on the initial DO concentration in the River as well as the BOD loads and DO concentrations in the storm water.

Coliform Bacteria. The data collected on coliform during the synoptic surveys indicates that total and fecal coliform counts often exceed the State Water Quality Criteria during dry weather conditions. Coliform counts in the River after storm events usually increase by one or more orders of magnitude above the dry weather concentrations and remain high for several days after the storm event. However, the violations of coliform counts that occur during dry weather indicate that sources other than stormwater runoff may also be contributing to the coliform concentrations in the lower Hillsborough River.

Suspended Solids. Dry weather synoptic data in the lower Hillsborough River generally showed an increase in total suspended solids downstream from the Dam. This indicated that the Bay is a source of solids to the River. Stormwater runoff

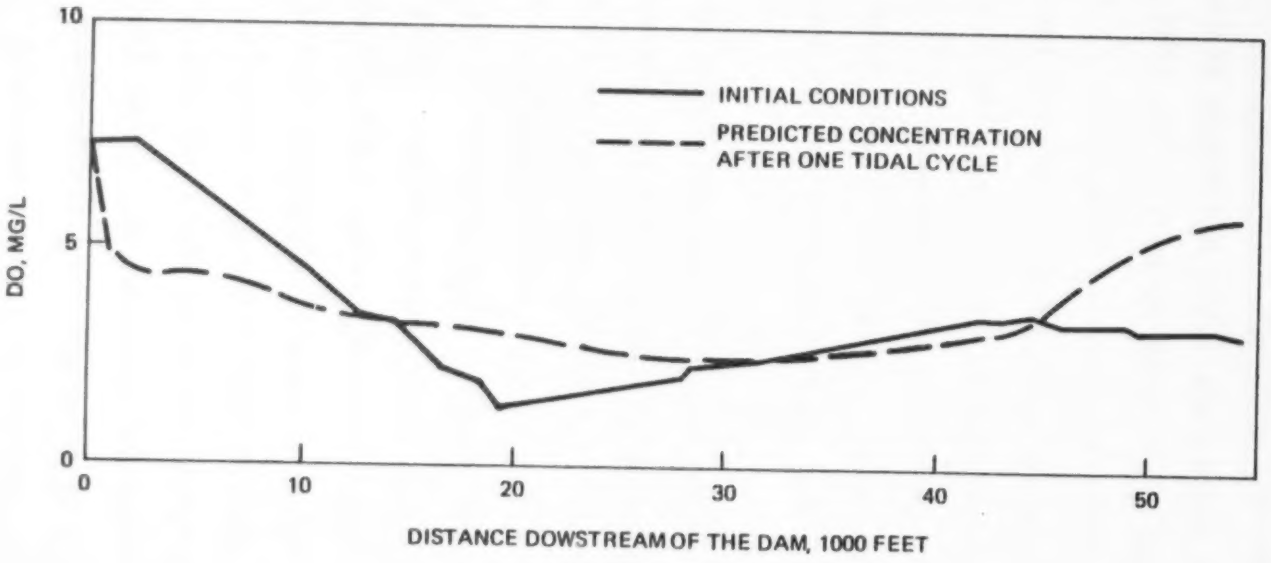

FIG. 6-1 DO PROFILES ALONG THE LOWER HILLSBOROUGH RIVER
FOR DESIGN STORM SIMULATION

does not appear to significantly affect the River in terms of solids loading. In both wet weather synoptic water quality surveys in the lower Hillsborough River (November 1982 and February 1983) the background total suspended solids concentration ranged from 10 to 20 mg/l. The effect of storm events caused the concentrations to rise by 10 to 40 mg/l for a brief period. Within 12 hours of the observed increases, the TSS levels dropped to their pre-storm levels. The increase in suspended solids in the River will increase turbidity to a certain extent. The main problem associated with stormwater solids, however, is that they transport metals from urban areas to the River.

Metals. The two synoptic surveys during which the metals data were obtained reflect both dry and wet weather conditions. The concentrations for the metals analyzed in these surveys are compared in Table 6-2. Copper concentrations violate State criteria after storm events. Lead concentrations increase after storm events, although these concentrations do not violate the State criteria. Zinc, however, shows lower concentrations during the November wet weather survey indicating that its source may be Hillsborough Bay rather than stormwater runoff.

The metals transported to the River via solids in stormwater runoff and Hillsborough Bay water settle at the River bottom and chelate with natural organic molecules in the sediments. During periods of anoxic conditions in the overlying

TABLE 6-2. COMPARISON OF METALS DATA FOR THE APRIL AND NOVEMBER, 1982 SURVEYS

Metal	Range of Concentration (ug/l) April 1982	Range of Concentration (ug/l) November 1982	Water Quality Criteria
Aluminum	50-530	-	1,500
Copper	3-6	13-57	15
Lead	4-26	8-22	50
Dissolved Lead	-	4-20	-
Zinc	20-90	4-22	30

waters, these metals may be released from the sediments and recycled to the water column.

Nutrients. From the synoptic survey data, concentrations of ammonia-nitrogen, nitrates and nitrites in the lower Hillsborough River do not appear to cause significant problems in the River, although algal blooms are often observed during periods of low freshwater flows. In general, nutrient concentrations were found to be higher in the downstream reaches in nearly all the surveys. This indicates that the downstream reaches of the River are affected by nutrients transported upriver from Hillsborough Bay.

Bottom Sediments. Thick organic muds comprise the River bottom in the downstream segments of the lower Hillsborough River. This material is the accumulation of many years of sludge discharges by the Water Department, the settling of metals and other solids from stormwater runoff and the upstream transport of material from Hillsborough Bay. The characteristics of the River bottom generally improve in the upstream direction. In River segments near 22nd Street the River bottom is scoured during periods of high freshwater discharge. Material that is transported to the upstream segments by estuarine circulation (bottom layer intrusion) during periods of low freshwater flow is resuspended during high flows and settles out again in the downstream reaches where velocities decrease.

River sediment analyses were performed at several locations in December, 1980 by the City of Tampa Department of Sanitary Sewers. The results of this sampling indicated that the River bottom contains more silt and decaying material proceeding downstream where the velocity is decreased and where saltwater intrusion predominates. The concentration ranges for various parameters are presented in Table 6-3. There is high organic and nutrient content in these sediments.

During the sediment oxygen demand experiments conducted in April, 1981 and August, 1982 (discussed in detail in Chapter 4) sediment samples were obtained at three stations and analyzed for quality and particle size distribution. Table 6-4 presents a comparison of dry and wet weather sediment quality and Table 6-5 compares the particle size distributions for different sampling periods. Station SOD1, located between Platt Street and Columbus Drive, exhibits very few differences in sediment quality and in particle size distribution for the two samples analyzed. This indicates that the composition of benthic material in this

TABLE 6-3. CONCENTRATION RANGES FOR LOWER HILLSBOROUGH RIVER SEDIMENT ANALYSIS, DECEMBER, 1980

Parameter	Range of concentrations
COD (mg/l)	4,000 - 18,500
TKN (mg/l)	96 - 325
pH	7.3 - 8.0
Total Solids (%)	3 - 22
Volatile Solids (%)	6 - 17
Aluminum (mg/l)	150 - 1,710

segment of the River is fairly constant throughout the year and is not affected by high freshwater flows. The sediments at station SOD2, located between Columbus Drive and Sligh Avenue, reflect a three-to-five-fold increase in August, 1982 in COD, TKN, aluminum and lead concentrations as compared to April, 1981. The particle size distributions are also very different. In the April sample very fine silt and clay appear to be the predominant components, whereas in the August sample nearly half of the particles are larger than 850 microns. This appears to be a direct result of resuspension and downstream transport of finer sediments by the high freshwater flow. Sediment quality at Station SOD3, located near Sligh Avenue, represents some increases in COD, TKN, aluminum and lead concentrations from April, 1981 through August, 1982, but the overall particle distribution is about the same. This Station, too, is subject to

TABLE 6-4. HIGH AND LOW FLOW SEDIMENT QUALITY IN THE LOWER HILLSBOROUGH RIVER

Station[1]	Date	Fresh-water Flow[2] (cfs)	COD (mg/l)	TKN (mg/l)	pH	Density (wet)	Total solids (%)	Volatile solids (%)	Al (mg/kg)	Pb (mg/kg)
SOD1	4/10/81	32.2	31,387	776	7.47	1.35	42.4	5.8	5,093	524
	8/12/82	802	32,173	874	7.87	1.46	48.0	4.6	5,664	413
SOD2	4/8/81	52.3	22,039	630	7.39	1.67	42.3	4.8	3,037	109
	8/12/82	802	61,694	3,150	7.90	1.31	32.0	11.5	16,207	446
SOD3	4/9/81	52.3	16,717	594	7.23	1.54	58.9	3.6	1,418	97
	8/12/81	802	28,822	673	7.34	1.52	62.4	3.3	3,560	152

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1. See Figure 4-1 for station location.
2. Includes average daily flows from Hillsborough Reservoir and Sulphur Springs.

TABLE 6-5. HIGH AND LOW FLOW PARTICLE SIZE DISTRIBUTION IN THE LOWER HILLSBOROUGH RIVER SEDIMENTS

Station	Date	Fresh-water Flow (cfs)	Distribution (%) for Size Range (u)						
			> 850	425-850	250-425	180-250	150-180	75-150	< 75
SOD1	4/10/81	32.2	5.73	6.17	12.67	14.22	20.90	32.83	4.22
	8/12/82	802	7.09	6.29	14.96	15.77	23.84	28.96	3.09
SOD2	4/8/81	52.3	0.63	1.26	6.07	18.27	31.29	41.25	1.24
	8/12/83	802	43.14(1)	7.78	4.40	3.41	8.71	29.38	3.18
SOD3	4/9/81	52.3	4.99	5.08	12.54	13.94	33.67	27.82	1.96
	8/12/82	802	3.75	3.46	8.49	8.43	22.44	50.92	2.50

1. See Figure 4-1 for station location.
2. Some large particles were formed when the clays solidified during the drying process.

saline wedge activity during periods of moderate freshwater discharge. As a result, a certain degree of change in sediment quality is expected.

In general the concentrations of COD, TKN and aluminum are much higher in the April, 1981 and August, 1982 sediment samples than in the December, 1980 samples. This could be due to seasonal fluctuations of sediment quality.

As discussed in Chapter 4, the bottom material exerts an oxygen demand in the water column, particularly during long periods of low freshwater flow when the estuary is insufficiently flushed.

Table 6-6 presents a summary of the major sources and effects of water quality problems on the lower Hillsborough River.

TABLE 6-6. SUMMARY OF SOURCES AND THEIR EFFECTS ON WATER QUALITY IN THE LOWER HILLSBOROUGH RIVER

Cause	Effects
Tidal Forces	Saline wedge depresses DO concentration; nutrients transported upriver from Bay water; organic material transported and deposited in the River.
Low Freshwater Discharge	Salinity penetrates upstream; DO concentrations depressed; benthic oxygen demand increases due to insufficient flushing.
Stormwater Runoff	Coliform bacteria levels violate standards; sediments transport metals to River.
Benthic Deposits	DO depletion is significant in downstream areas.
Unknown Sources	Coliform bacteria levels violate standards in dry weather.

Pollutant Loading Estimates

As a supplement to WQON model runs which have been used to analyze the impact of stormwater on the lower Hillsborough River, estimates of pollutant loadings to the lower River from various sources have been developed. The purposes of these estimates are to:

1. Define the relative long-term impact of external (Reservoir, stormwater) and internal (sediments) oxygen demand, solids, and nutrient loadings;
2. Determine the quantity of intrusion of Hillsborough Bay water (and associated pollutants) in the River under varying freshwater flow conditions, and
3. Compare the relative influence of stormwater with other sources under design storm conditions.

Estimates of pollutant loadings from various inflow sources to the lower Hillsborough River and subsequently to Hillsborough Bay were calculated using available data. The primary sources of inflow to the River are Hillsborough Bay, Reservoir releases and stormwater runoff.

A range of stormwater inflows was calculated based on the annual runoff volume generated by the S/SWMM model for selected dry, average and wet years (1). The inflow for an average year is 37 cfs and the dry and wet years contribute 27 and 43 cfs, respectively.

Average yearly discharges for the past 40 years from the USGS gage at Tampa Dam were reviewed to establish a range of

Reservoir releases. The average yearly discharge from 1939-1978 was approximately 600 cfs. The period from 1962-1981 yielded an average discharge of 400 cfs and a discharge of 250 cfs was obtained for the ten-year period from 1972-1981. Lower flows have been released from the Reservoir in the last two decades because of increased use of this source as a water supply as well as drier climatic conditions and the construction of the Tampa Bypass Canal. During periods of high Reservoir releases no more than 1,500 to 2,000 cfs is now discharged from Tampa Dam, with the remainder being diverted to the Bypass Canal. In earlier years releases of up to 30,000 cfs were recorded at the Dam, thus resulting in higher average flows.

Table 6-7 shows the average concentrations and average yearly loadings of BOD, TSS and various nutrients from stormwater runoff, Reservoir releases and River bottom sediments. Average parameter concentrations in stormwater were obtained from the Phase II Report (1). Synoptic data at 22nd Street during dry weather surveys with a Reservoir release were assumed to be representative of parameter concentrations in the Hillsborough Reservoir.

The yearly loadings presented in Table 6-7 were calculated assuming average inflow conditions (37 cfs from stormwater and 400 cfs from the Reservoir). The yearly oxygen demand from River bottom sediments was calculated assuming low and high flow conditions are each present six months of the year. The loadings show that, in general, the Reservoir contributes more pollutants

TABLE 6-7. AVERAGE INFLOW CONCENTRATIONS AND AVERAGE YEARLY LOADINGS TO THE LOWER HILLSBOROUGH RIVER AND HILLSBOROUGH BAY

	Average Concentration			Average Yearly Loading ($x10^3$ lbs)		
Parameter	Stormwater runoff (mg/l)	Reservoir release (mg/l)	Bottom sediments ($g/m^2/d$)	Stormwater runoff	Reservoir release	Bottom sediments
Oxygen demand	14(1)	1.5(1)	1.1-3.6(2) 2.6-9.8(3)	1,020	1,180	920(4)
Total Suspended solids	40	7		2,900	5,500	
Ortho-P	0.14	0.32		10	250	
Total P	1.38	0.34		100	270	
Organic N	0.91	0.98		70	770	
Ammonia-N	0.38	0.06		30	50	
Nitrate-N	1.89	0.05		140	40	
Nitrite-N	0.02	0.002		1	1.5	

1. 5-day Biochemical Oxygen Demand.
2. SOD Rates under high freshwater flow conditions.
3. SOD Rates under low freshwater flow conditions.
4. Assumes 6 months of high flow and 6 months of low flow conditions.

to the estuary than stormwater runoff with the exception of nitrates which are very high in stormwater and ammonia and oxygen demand, which are almost the same for the two sources.

Table 6-7, however, does not present the total picture of pollutant loadings to the lower Hillsborough River. Upstream penetration of Hillsborough Bay water due to tidal activity introduces additional solids, nutrients and BOD to the lower Hillsborough River. The influence of the Bay, however, cannot be quantified in terms of a yearly pollutant load. The movement of tidal intrusion in and out of the estuary results in zero net intrusion over a long period of time. The addition of Reservoir releases and stormwater inflows to the River results in a net downstream flow to Hillsborough Bay. Nevertheless, the presence of Bay water in the lower Hillsborough River does degrade water quality, as was observed in the analyses of continuous and synoptic data in earlier chapters.

One approach to estimating the effects of the Bay on River water quality is to calculate an instantaneous pollutant load in the River under various degrees of saltwater intrusion. Figure 6-2 presents a river profile of saltwater intrusion for various freshwater flow conditions as measured during the synoptic surveys.

Table 6-8 compares various pollutant loads present in the fresh water and salt water layers for the profiles in Figure 6-2. The average concentrations of pollutants measured at Platt Street during the dry weather synoptic surveys were assumed

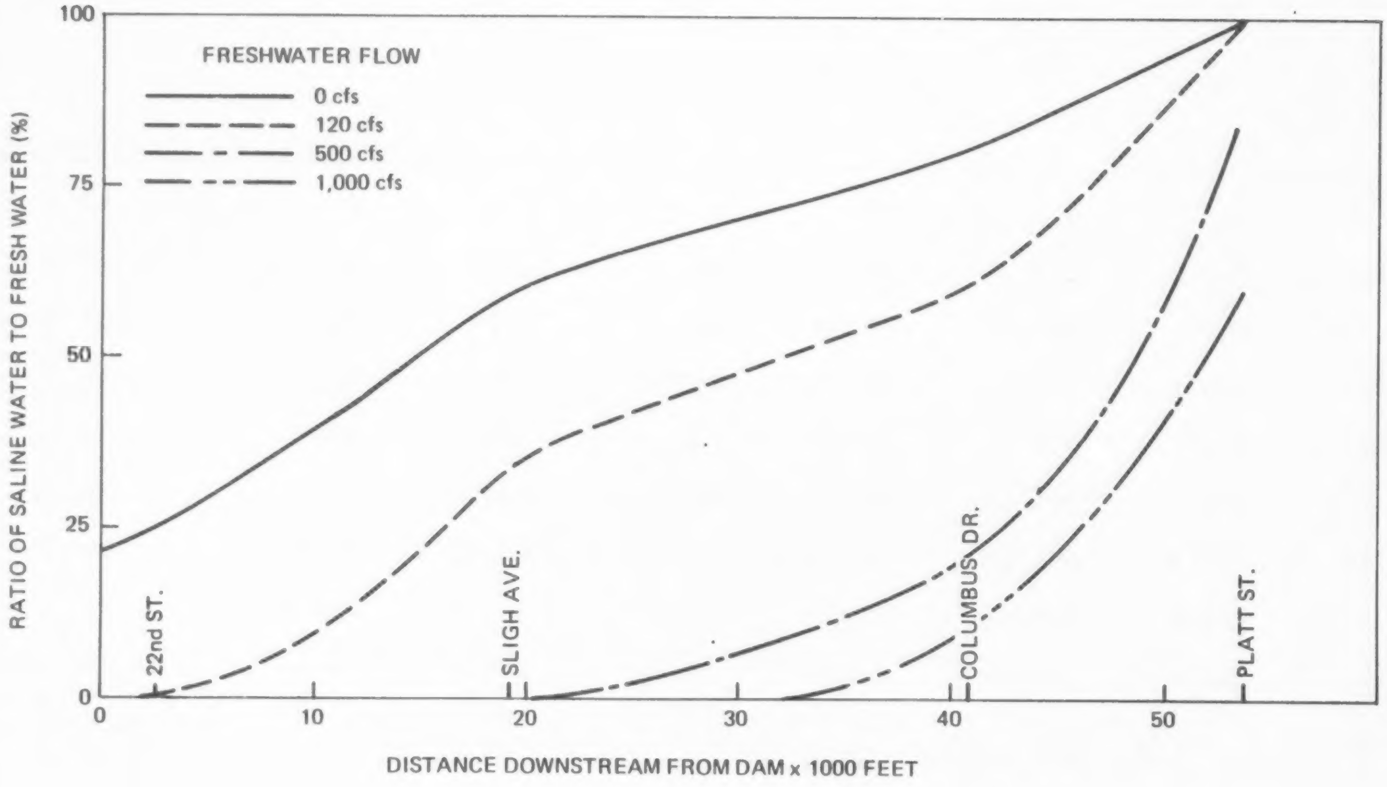


FIG. 6-2 PROFILES OF SALTWATER INTRUSION IN THE LOWER HILLSBOROUGH RIVER FOR VARIOUS FRESHWATER FLOW CONDITIONS

TABLE 6-8. POLLUTANT LOADS IN DESIGN STORM RUNOFF AND FRESH AND SALT WATER LAYERS IN THE LOWER HILLSBOROUGH RIVER

Parameter	Average concentrations in Hillsborough Bay (mg/l)	Pollutant Loads in Lower Hillsborough River (lbs)						
		0 cfs		120 cfs		500 cfs		Design storm runoff(1)
		Fresh water(1)	Salt water	Fresh water	Salt water	Fresh water	Salt water	
BOD	2.71	2,500	11,500	4,000	8,800	6,900	3,400	22,300
TSS	55.	11,400	233,500	18,500	178,400	32,300	69,200	63,700
Ortho-P	0.63	500	2,700	840	2,000	1,500	800	220
Total P	0.67	550	2,800	900	2,200	1,600	800	2,200
Organic N	1.23	1,600	5,200	2,600	4,000	4,500	1,600	1,400
Ammonia N	0.34	100	1,400	160	1,100	300	400	600
Nitrate-N	0.04	80	170	130	130	230	50	3,000
Nitrite-N	0.01	3	40	5	30	9	15	30

1. Based on concentrations in Table 6-6.

to be representative of Hillsborough Bay water. The pollutant loadings from the 1-month 2-hour design storm discussed earlier are also presented in this table. These loadings are based on the average pollutant concentrations shown in Table 6-7.

The estimated loads in Table 6-8 show the strong influence of Hillsborough Bay intrusion particularly for solids and ammonia. Stormwater runoff from the 1-month 2-hour design storm transports high BOD, total phosphorus and nitrate-nitrogen loads relative to what is already present in the River. Stormwater BOD may comprise 60 to 70 percent of the total load in the River after a storm, total phosphorus loading from the storm may be 40 to 50 percent of the total load, and approximately 90 percent of the nitrates in the River after a storm would be due to stormwater runoff.

Water Quality Improvement Alternatives

The water quality problems of the Hillsborough River are due to many interactive factors. Several alternatives have been developed to address the concerns of low dissolved oxygen concentrations, high coliform bacteria levels and high nutrient concentrations in the River. Each alternative is designed to counteract the negative impacts on water quality due to one major source. The alternatives are presented as follows.

Salt Water Barrier. A salt water barrier erected at the mouth of the lower Hillsborough River would prevent Hillsborough Bay water from moving upstream and bringing in organic deposits. The elimination of salinity would improve dissolved oxygen concentrations in the River. Phosphorus and other nutrients would not enter the River from the Bay and sediment accumulation or the River bottom would decrease. A salt water barrier, however, may affect the upstream migration of salt water species.

Regulation of Reservoir Releases. As discussed in Chapter 2, the dissolved oxygen concentrations in the lower Hillsborough River are dependent on the freshwater flows from Hillsborough Reservoir and the resulting location of the saline wedge. If the Reservoir releases could be regulated so as to assure a continual freshwater flow to the River, improvements in dissolved oxygen concentrations would be observed along the River. The length of the River in which DO improvements would result would depend on the magnitude of the freshwater release. Table 6-9 estimates the extent of average DO levels above 5.0 mg/l for various continual releases from the Reservoir.

TABLE 6-9. IMPROVEMENTS IN DO CONCENTRATIONS AND NECESSARY FRESHWATER RELEASES

Extent of river with DO>5.0 mg/l	Continuous reservoir release (cfs)
Tampa Dam to 22nd Street	50
Tampa Dam to Sligh Avenue	200
Tampa Dam to Columbus Drive	1,000
Tampa Dam to Platt Street	>1,500

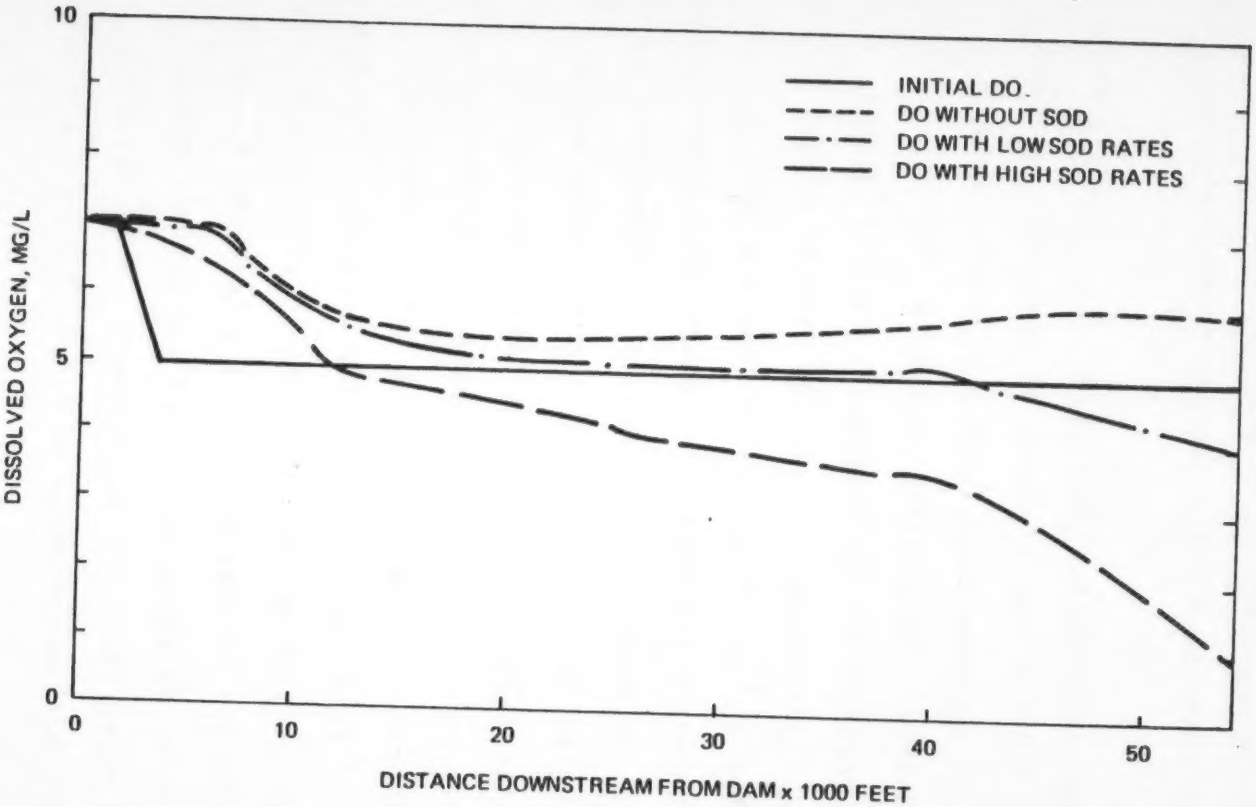
With the existence of a salt water barrier at the mouth of the River, a continuous Reservoir release would be desirable to prevent stagnant conditions in the River; however, high discharges would not be necessary since salinity intrusion would be nonexistent.

Dredging. The downstream segments of the River bottom are covered with thick organic muds that exert a significant oxygen demand on the water column. Dredging of the benthic deposits would eliminate the oxygen demand for a time, but it is likely that material from Hillsborough Bay would continue to be transported and deposited upstream and solids from stormwater runoff would again accumulate in the River bottom. If a salt water barrier was constructed, benthic deposition would occur primarily from stormwater runoff and high freshwater flows would transport and deposit most of the material behind the barrier. Unless dredged regularly, this material could create nuisance conditions during long periods of low freshwater releases. Based on available information the longitudinal extent of dredging activity is estimated to be from Buffalo Avenue downstream to Platt Street. Additional surveys and sediment core samples would be necessary to confirm the length of the River to be dredged as well as the depth of organic deposits.

A WQON simulation was performed to predict water quality conditions after dredging of the River bottom. A salt water barrier was assumed at the mouth of the estuary resulting in freshwater flow along the entire River. A discharge of 50 cfs was assumed for the freshwater release from the Reservoir and 40 cfs for the Sulphur Spring inflow. A background DO of 5.0 mg/l was assumed along the entire River with a BOD background level of 1.0 mg/l. The WQON model was first run for five days with SOD rates from the low flow and high flow tests (Table 4-1). The SOD rates were then removed and the simulation was repeated. The results for all runs are presented in Figure 6-3. The simulation without SOD predicts a DO concentration of 5 to 7 mg/l in the entire River. The simulations with SOD rates, however, show a decrease in dissolved oxygen concentrations primarily in the lower segments of the River. DO concentrations in the simulation with high SOD rates are up to 5 mg/l less than predicted concentrations without SOD.

Disinfection. Coliform counts are very high in the lower Hillsborough River for at least three days after most storm events. Furthermore, measurements of coliform during dry weather indicate that other sources of coliform in the River are still active and result in frequent violations of State Water Quality Criteria.

In order to reduce coliform bacteria levels in the River to within the Standards criteria, first the dry weather sources of coliform have to be investigated and controlled. To prevent violations of coliform counts due to stormwater runoff, control facilities would have to be built to intercept and disinfect stormwater runoff before the it enters the River.



NOTE: SALTWATER BARRIER
ASSUMED AT RIVER MOUTH
RESERVOIR RELEASE 50 cfs
SULPHUR SPRINGS 40 cfs

FIG. 6-3 DISSOLVED OXYGEN PROFILES FOR A RIVER SIMULATION WITH AND WITHOUT SEDIMENT OXYGEN DEMAND

These control facilties would create significant capital as well as annual O&M costs. However, the reduction in coliform counts has to be on the order of 90 percent of the inflow concentration in order to achieve desired concentrations in the River.

Stormwater Management Plan Alternative. The Stormwater Management Plan for the City of Tampa as presented in Phase III study is aimed at reducing stormwater pollutants loads to the best degree possible. The greatest potential for this reduction lies in the enforcement of the Stormwater Permitting Rule which requires any new developments within the City to either retain or detain and filter the runoff generated from one inch of rainfall.

As presented in the Phase III Report (2), flood mitigation by runoff reduction measures could result in stormwater runoff reductions of up to 50 percent in the overall study area. Since other flood mitigation measures will probably be used in conjunction with runoff reduction measures, a conservative stormwater load reduction of 30 percent was assumed for a demonstration of River water quality improvements. The design storm discussed earlier was simulated again with reduced loads. Figure 6-4 shows the initial DO concentrations and the predicted concentrations for existing and future (30 percent removal) conditions 18 hours after the storm event. A DO sag still occurs along the River but improvements of 0.2 to 0.5 mg/l are observed.

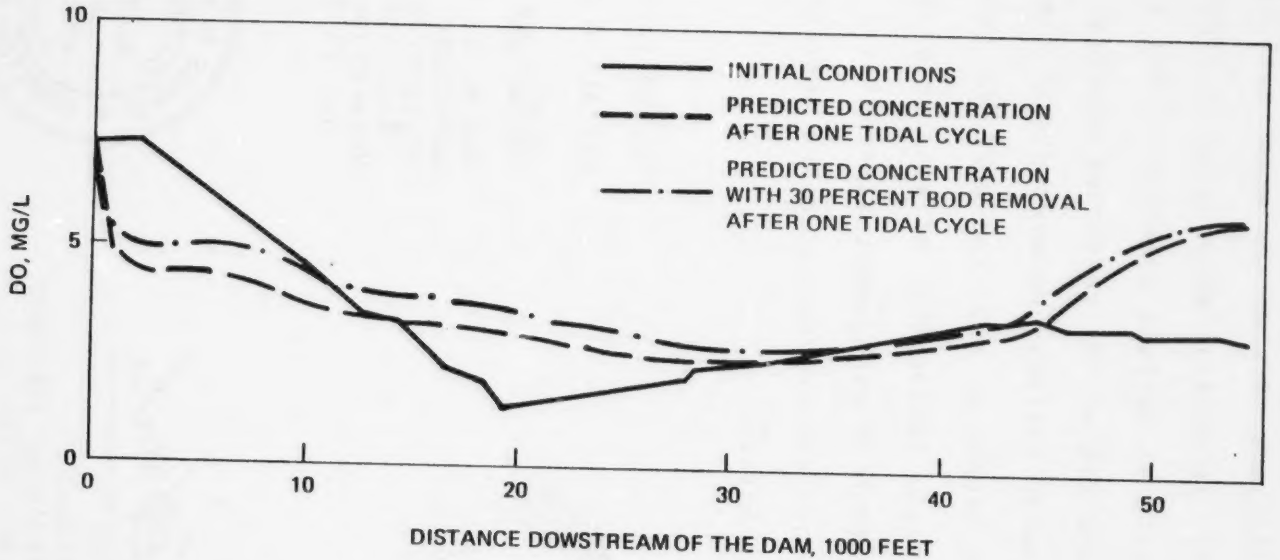


FIG. 6-4 EXISTING AND FUTURE (30 PERCENT BOD REMOVAL) DO PROFILES FOR DESIGN STORM SIMULATION

Summary

A complex interaction of tides, freshwater flows, and meteorological conditions affects the water quality of the lower Hillsborough River. In general water quality conditions can improve or degenerate at various locations along the River based on the change in any one of the governing factors. In the same light, long-term water quality improvements in the lower Hillsborough River cannot be realized with the reduction or alteration of only one factor that affects water quality. Rather, an interaction of management alternatives will be necessary to best achieve and maintain the desired water quality conditions in this River.

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